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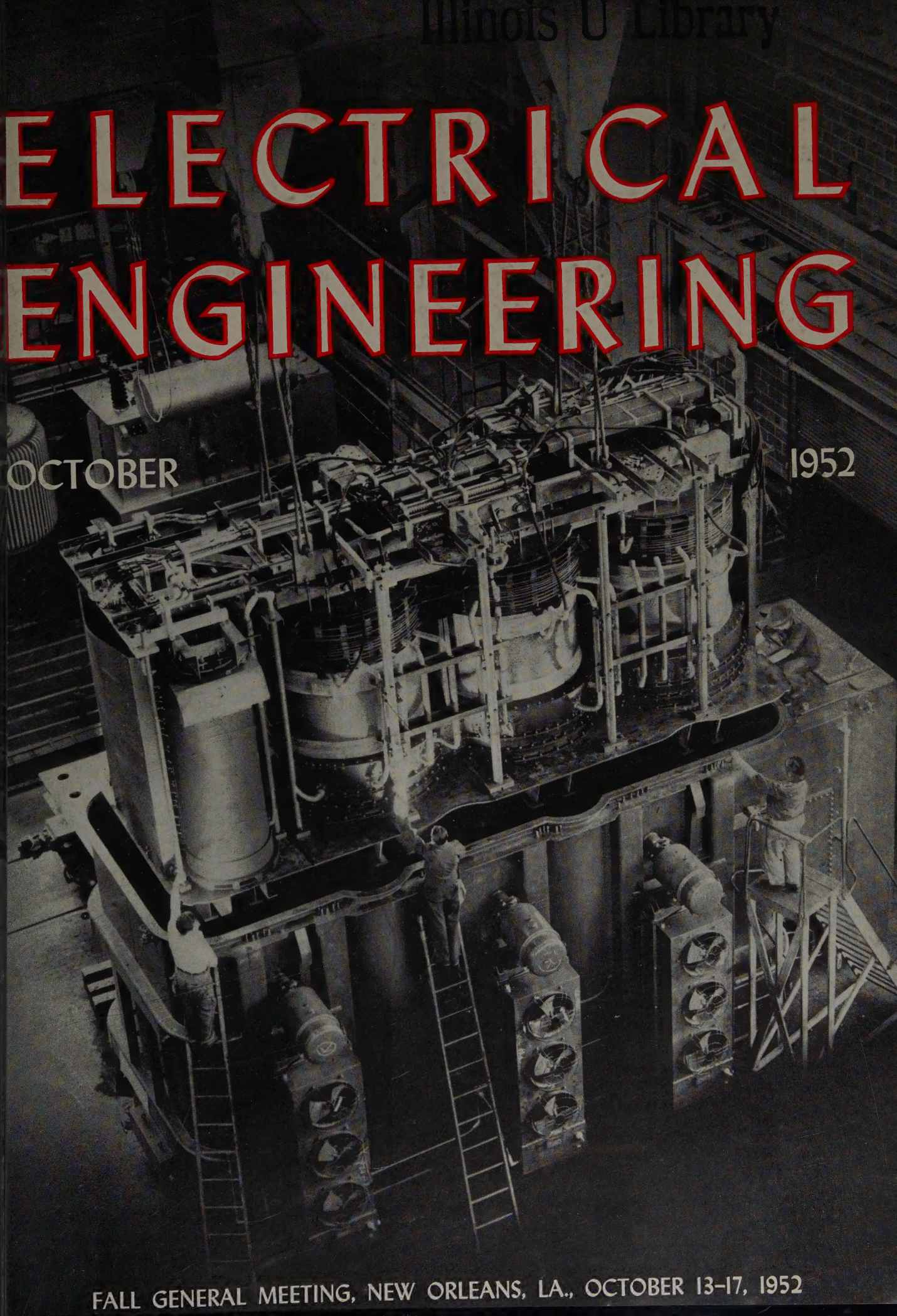
ELECTRICAL ENGINEERING

OCTOBER 1952



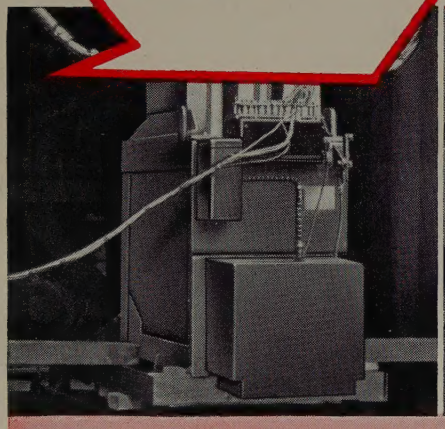
FALL GENERAL MEETING, NEW ORLEANS, LA., OCTOBER 13-17, 1952

"A to Z" Testing Takes Guesswork Out of Switchgear Performance

Assures Quick Installation . . . Proper Operation . . . Long Life

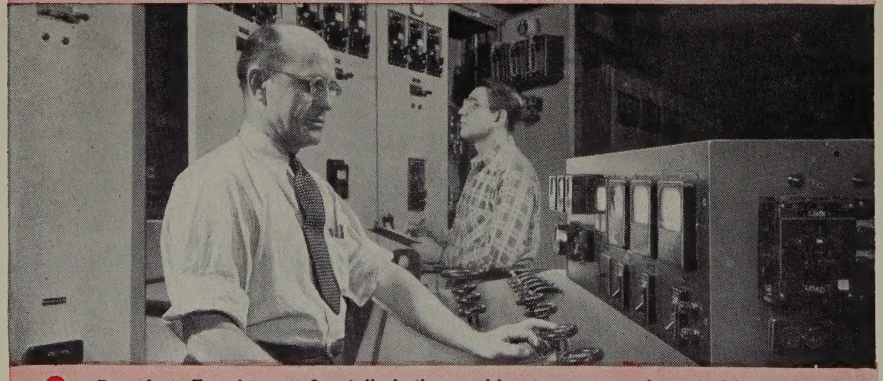
THREE TYPES OF TESTS — design . . . inspection . . . and routine tests are used to check and double check Allis-Chalmers switchgear. Briefly, here is the careful, orderly system of tests used to assure you of a quality product.

ALLIS-CHALMERS METAL-CLAD Switchgear



1. Design Testing — Most spectacular in the whole long series of design tests is the short circuit test of a Metal-Clad Switchgear breaker. Other tests in this series include impulse, temperature, dielectric, life and radio interference tests.

2. Inspection Testing — Typical is this check of ratio and phase angle accuracy of an instrument transformer using highly accurate Silsbee set. Perfect operation of assembly is based on perfect operation of parts.



3. Routine Testing — Specially built portable test wagon makes possible testing of completed switchgear right on the assembly line. This versatile unit tests: circuits, meters, interlocks, control schemes, throwovers, phasing, potential and circuit transformers, relays of all types, dc equipment, etc.

TESTS

Design Tests:

short circuit interrupting tests
momentary current test
temperature rise
dielectric test — one minute — 60 cycle
impulse voltage test
operational life test
radio interference test
corona level
speed graph
minimum and maximum closing voltage test
repetitive operation test
transformer core loss test
transformer saturation test
transformer impulse test

Routine Tests:

one minute, 60 cycle dielectric test on primary and secondary circuits
closing and tripping test
minimum and maximum voltage test
speed graph
Check of: watthour meters, overcurrent and directional relays, instruments, etc. A 3 phase secondary current load and normal 3 phase potential is used
Control tests of: interlocks, throwover schemes, sequence operational schemes, control schemes

Inspection Tests:

instrument transformer dielectric test
instrument transformer ratio and phase angle tests
analytical tests of raw materials such as: copper, silver, steel, aluminum, brass, *Bakelite* insulation
inspection of component materials: meters, relays, insulation, porcelain

In addition to testing every removable element and every stationary element to assure proper performance, every one is built to master jigs to assure easy installation and interchangeability. For switchgear you can depend on, call your nearby Allis-Chalmers district office. Or write Allis-Chalmers, Milwaukee 1, Wis.

A-3815

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A-C ALLIS-CHALMERS

ELECTRICAL ENGINEERING

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OCTOBER
1952

VOL. 71 NO. 10

The Cover: The largest autotransformer ever to be built by the General Electric Company is shown being lowered into its tank at the company's Pittsfield (Mass.) Works. To be installed in the Illinois Power Company system, the 3-phase 60-cycle autotransformer will be used to step up voltage from 138 to 230 kv, providing regulated output of 156,000 kva varying over a range of 10 per cent below and 10 per cent above the 138,000 grounded Y.

We Begin a New Institute Year.....D. A. Quarles . . . 867
Encouragement of Technical Training for Young People.....O. W. Eshbach . . . 869
Radio Noise in Relation to the Design of High-Voltage Transmission Lines.....H. L. Rorden, R. S. Gens . . . 873
Possible Industrial Hazards in the Use of Microwave Radiation.....H. M. Hines, J. E. Randall . . . 879
Nation-wide Telephone Numbering Plan.....W. H. Nunn . . . 884
Automatic Toll Switching Systems.....F. F. Shipley . . . 889
Safety Aspects of Grounding Portable Equipment.....H. B. Whitaker . . . 897
Further Data on the Design of Eccles-Jordan Flip-Flops.....Morris Rubinoff . . . 905
Industrial Applications of Magnetic Amplifiers.....R. W. Moore . . . 912
Ferroelectric Storage Elements for Digital Computers and Switching Systems.....J. R. Anderson . . . 916
Standard Basic Impulse Insulation Levels: 450 to 1,045 Kv Inclusive.....Joint Committee Report . . . 922
Production Impulse Testing of Distribution Transformers.....E. D. Treanor, H. C. Stewart, J. E. Holcomb . . . 925
Multipoint Telemetering System Using Teletype Transmission.....A. J. Hornfeck, G. R. Markow . . . 929
The Phosphor-Phototube Radiation Detector.....D. P. Cole, P. A. Duffy, M. E. Hayes, W. S. Lusby, E. L. Webb . . . 935

TECHNICAL PAPER DIGESTS

Measurements on New Transformer Insulation.....W. L. Teague, J. H. McWhirter . . . 872
Dial-Reading Translator for Digital Machine Inputs.....A. L. Klein, K. P. Gow . . . 882
Progress in Design of Diesel-Electric Switchers.....R. W. Barrell . . . 883
Annual Carrying Charges.....P. H. Jeynes . . . 903
Tensorial Analysis of Transmission Systems—II.....Gabriel Kron . . . 904
Wave Filter Characteristics by a Direct Method.....R. C. Taylor, C. U. Watts . . . 911
Present Worth.....P. H. Jeynes . . . 923
Two-Phase A-C Servo Motor Operation.....M. A. Steinhacker, W. E. Meserve . . . 924

MISCELLANEOUS SHORT ITEMS: Railroads Report 900% Power Gain, 871; Delivery of Stator Poses Transportation Problems, 888

Institute Activities.....940
AIEE Personalities, 953; Obituary, 954; Membership, 955

Of Current Interest.....956
Letters to the Editor, 960; New Books, 962

Industrial Notes.....18A
New Products, 32A; Trade Literature, 66A

Index to Advertisers.....94A

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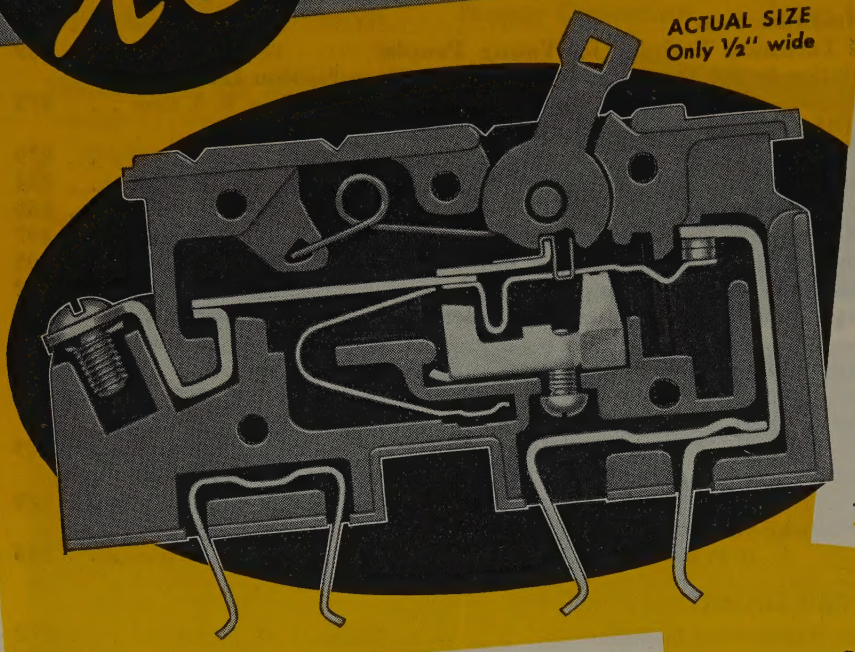
See XO CIRCUIT BREAKER
FOR LOW-COST LOAD CENTERS



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Only ½" wide

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Climaxing nearly twenty years' design leadership in the residential circuit breaker field, Square D now offers this new and remarkably simple type of mechanism. Study the sectional illustration at left—see how simplicity of design (only 3 moving parts) provides accurate, positive operation! See how this same simplicity gives you every worthwhile operating characteristic you want in a circuit breaker—without cost penalty!

QUICK-MAKE, QUICK-BREAK at no extra cost and without use of coil springs. Spring shown above merely positions handle—has no function in breaker operation.

Positive Operation insured by action of handle cam directly against contact arm. No spring coupling.

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AMBIENT COMPENSATED at no extra cost. Additional bimetal automatically regulates operation to surrounding atmospheric conditions—prevents needless tripping.

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SHOCK RESISTANT. Simplicity of design, light weight moving parts, and new type spring loading—all combine to make breaker unusually resistant to vibration or shock.

Plug-In Mounting for easy, fast connection to line bus. Steel reinforced, positive pressure clip has been performance-proved on millions of Square D products.

NON-TAMPERABLE ASSEMBLY. Breaker unit width varies with capacity. Impossible to interchange high capacity ratings with smaller sizes.

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ONLY 3 COMPONENTS

- box and interior
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1 TO 32 CIRCUITS WITH ONLY 6 ENCLOSURES

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HIGHLIGHTS .....

Meetings in This Issue. More than 500 persons attended this year's Pacific General Meeting in Phoenix, Ariz. Many of the technical papers presented during the 15 sessions considered problems of the Southwest (*pages 945–8*). Tentative technical programs for three future meetings are included in this issue: the Middle Eastern District Meeting in Toledo (*pages 940–2*); the Fall General Meeting in New Orleans (*pages 943–5*); and the Conference on Recording and Controlling Instruments (*pages 948–9*).

Presidential Address. In his address at the Pacific General Meeting, President Quarles "looks at the record" as the Institute begins a new year (*pages 867–8*).

Technical Training for Young People. "The greatest single factor in providing the proper educational balance among our future leaders is the encouragement of young people to understand the physical world . . . ." Northwestern University's Dean Eshbach shows why and how this factor must be considered by today's educators (*pages 869–71*).

Possible Industrial Hazards in the Use of Microwave Radiation. Although much is known about the behavior of microwave radiations in space, there are many unknowns as to what effect they have on living organisms. The laboratory results show that animals' internal organs are heated by these high-frequency radiations, sometimes to a dangerous degree (*pages 879–81*).

Effect of Radio Noise on High-Voltage Transmission-Line Design. This article is concerned with the elimination of interference in domestic amplitude-modulated radio receivers. It provides data to help the user of high-voltage equipment specify adequate but as inexpensive equipment as is practicable (*pages 873–9*).

Basic Impulse Insulation Levels. This report presents the Standard Basic Impulse Insulation Levels adopted in May 1950, and also indicates their allocation (*page 922*).

Nation-wide Telephone Numbering System. In order for a telephone subscriber in one section of the country to dial directly any other telephone in the United States and Canada, a simple system of numbering had to be developed. How the new numbering system will be eventually employed is explained (*pages 884–8*).

Safety Aspects of Grounding Portable Equipment. The purpose of grounding exposed conductive materials enclosing electric equipment is to prevent potentials above ground on the equipment. Such potentials might cause passage of dangerous currents through bodies of persons if they touch the equipment and ground. Methods of grounding are described (*pages 897–902*).

Automatic Toll Switching Systems. The last of a series of four articles about the nation-wide system of toll dialing deals with the automatic switching systems by means of which any subscriber eventually will be able to dial directly any other telephone in the United States and Canada (*pages 889–97*).

Eccles-Jordan Flip-Flop Design. In addition to presenting a prototype of those used in large digital computers and a graphical design technique, a preliminary analysis is carried through for the rise time of the on-going grid. The results may be used to show the influence of transpose capacitance on speed of flip-flop switching (*pages 905–10*).

Ferroelectric Storage Devices. These devices offer the possibility of operation from low-voltage circuits such as transistors, do not consume power during the storage period, can provide storage for long periods of time without regeneration, and are adaptable to a variety of circuit combinations (*pages 916–22*).

Multipoint Telemetering System Using Teletype Transmission. Telemetering has been used in the electrical industry for many years for operating power stations and substations. The application of electric telemetering to the field of industrial processes, although more recent, is becoming increasingly important. The use of teletype transmission in a telemetering system is described in this article (*pages 29–35*).

Magnetic Amplifiers. Many of the important characteristics of "Magamps" are listed, together with a description of a few typical industrial applications of these devices (*pages 929–35*).

Impulse Testing of Distribution Transformers. This article traces the use of this kind of testing from the period prior to 1930 up to the present. It sums up the improvements learned from experience with production impulse testing, but also mentions its limitations such as in testing for lightning stresses (*pages 925–8*).

Phosphor-Phototube Radiation Detector. The combining of a newly developed phosphor—anthracene and cadmium tungstate—and a photomultiplier tube has resulted in a portable radiation detector of excellent characteristics. The development of this new instrument is described in this issue (*pages 935–9*).

News Index

Institute Activities 940

Middle Eastern District Meeting Program 940
Future AIEE Meetings 940
Fall General Meeting Program 943
Pacific General Meeting Held 945
Conference on Recording and Controlling Instruments 948
Board of Directors Meets 949
Committee Activities 951
AIEE Personalities 953
Obituary 954
Membership 955

Of Current Interest 956

Light and Vision Institute 956
Future Meetings of Other Societies 957
Letters to the Editor 960
New Books 962

Bimonthly Publications

The first issues of the new bimonthly publications, *Communication and Electronics*, *Applications and Industry*, and *Power Apparatus and Systems*, have been released. Superseding the AIEE *Proceedings*, these publications contain the formally reviewed and approved numbered papers (exclusive of ACO's) presented at General and District Meetings. The publications are on an annual subscription basis. In consideration of payment of dues, members may receive one of the three publications; additional publications are offered to members at an annual subscription price of $2.50 each. Nonmembers may subscribe on an advance annual subscription basis of $5.00 each (plus 50 cents for foreign postage payable in advance in New York exchange). Single copies, when available, are $1.00 each. Discounts are allowed to libraries, publishers, and subscription agencies.

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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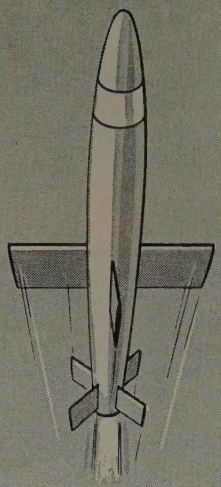
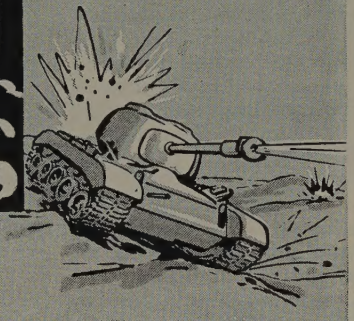
We've been solving automatic control problems for 37 years

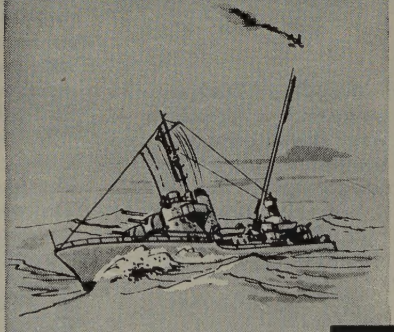


Controlling guided missiles in flight

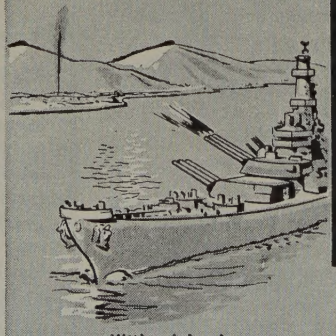
Knowing your whereabouts under all circumstances



Stabilizing the guns on bouncing tanks



Shooting down jet planes from the unstable decks of ships



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Take one part of the fantastic, mix thoroughly with Ford's engineering and production ability, and you've got the answer to another "impossible" automatic control problem. That has been the sum and substance of the Ford Instrument Company since 1915.

Stabilizing a gun on a bouncing tank or a ship's plunging deck; governing the unique movement of a torpedo; keeping a pilot informed of his whereabouts at all times and in all weather — Ford found the answer!

From the more than 16 acres of floor space that make up the engineering and production facilities of the Ford Instrument Company, come the mechanical, hydraulic, electro-mechanical and electronic instruments that bring us our "tomorrows" today! Research, development, design and production are being applied to control problems of both Industry and the Military.

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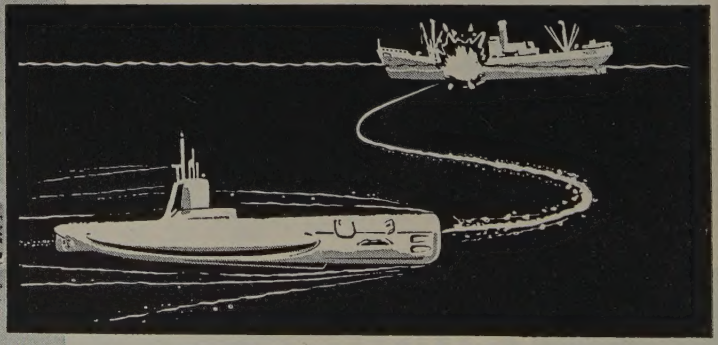

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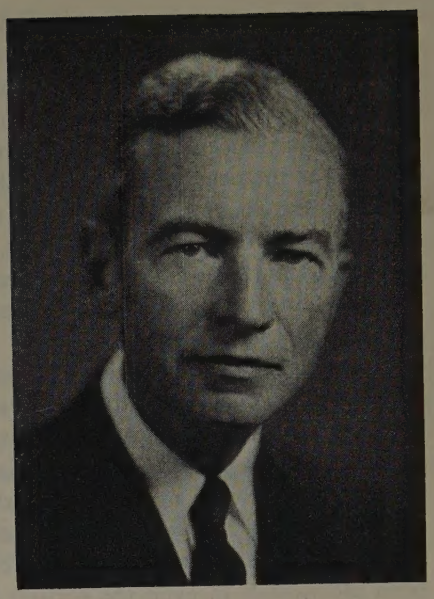
We Begin a New Institute Year

D. A. QUARLES
PRESIDENT AIEE



President Quarles, in an address before the recent Pacific General Meeting in Phoenix, evaluates the evolution in AIEE organization and policy as the Institute enters a new administrative year.

THIS IS MY first opportunity as AIEE President to address a meeting of the Institute. The formalities of announcing the election of officers and directors were carried out at the Summer General Meeting in Minneapolis, Minn., in June, but the new administrative year started the first of August. While we speak of a new administrative year, I am glad to note that the majority of the governing body actually carry over from the preceding year. Under our constitution, past presidents continue as members of the Board of Directors for 2 years, vice-presidents serve for 2 years, and directors are elected for 4 years. It happens that this year some 19 of the 26 members of the Board were actually members of the Board in the previous administrative year. I mention this to reassure you that while the president is new, the bulk of the administrative body is well seasoned.

Thanks to the fine co-operation of all concerned, I can report that our organization for the year ahead is substantially complete. The chairmen and members of the 17 general committees and the 11 professional committees of the Institute have been appointed and with a proper admixture of new blood and experienced personnel they are going concerns.

EVOLUTION OF THE INSTITUTE

THE TECHNICAL structure of the Institute has been undergoing an evolutionary change in the last 6 years or so and I believe we all can take considerable satisfaction in the results that have been achieved. The broad lines of this evolution were blocked out by the Board of Directors at its Asheville, N. C., meeting in 1946. The main objectives were to broaden and strengthen the technical structure by organizing it in five technical divisions, namely, Communications, General Applications, Industry, Power, and Science and Electronics; by increasing headquarters staff support of technical committee work; and by encouraging the formation of new committees and subcommittees to cover new or expanding areas of electrical technology. Today there are set up under these five divisions some 40 technical committees with almost 200 subcommittees, including such relatively new fields as electronics and nucleonics as evidence of the progressive policy that has been followed. While the organization and membership of these technical committees for the 1952–53 administrative year has been completed it must be flexible and subject to further evolutionary changes as conditions require. The guidance and control of the Institute's technical affairs are now vested in a Technical Operations Committee, newly organized this year to take over the functions of the previous Technical Advisory and Technical Program Committees. We believe we now have a very strong technical organization that properly emphasizes the essentially technical character of our Institute.

Paralleling this evolution in technical structure there is being inaugurated this year, after several years of planning and preparatory work, a new publication policy which will be of general interest to the members. The main features are

1. The *Proceedings* are replaced by three new publications to cover, respectively, *Communication and Electronics*, *Applications and Industry*, and *Power Apparatus and Systems*.
2. These will contain the formal *Transactions* papers in each field, plus discussion material.
3. Each member may elect to receive one of the new publications without charge. This is in addition to receiving *Electrical Engineering*, the character of which is unchanged.
4. The *Transactions* will be subdivided into the same afore-mentioned three technical parts and will be issued annually rather than semiannually.

The fact that the membership of the Institute has more than doubled in the last 10 years and is now approaching 50,000 is evidence of the youthful vigor of the organization. We have had record-breaking attendance at our general

Full text of an address presented at the AIEE Pacific General Meeting, Phoenix, Ariz., August 19–22, 1952.

D. A. Quarles, President AIEE, is president of the Sandia Corporation, Albuquerque, N. Mex.

and District meetings. In addition we have sponsored, at times jointly with other technical societies, technical conferences on subjects of wide current interest such as electronic computers, feedback control systems, and so forth. The success of these technical conferences is evidence of the need of our membership for an opportunity to meet and exchange up-to-date technical information in vital new areas of our technology, this as a supplement to the technical sessions at our general meetings where program limitations make it impracticable to give full coverage to the new subject matter. It is to the credit of our technical divisions and committees that this need has been recognized and that ways and means have been found to meet it on a substantially self-supporting basis.

September marked the Centennial of Engineering in Chicago, Ill. Some may have wondered just what engineering event of 100 years ago was celebrated. Obviously this was not the beginning of engineering since there have been individuals in even the earliest human societies who studied and solved the engineering problems of their times. Up to about 100 years ago organized engineering was largely a military art and this year commemorates the first establishment in this country of a civil, that is, nonmilitary, engineering organization. Our own electrical engineering institute branched off of the civil engineering mother body some 32 years later under the stimulation of the great new power and telephone developments. At the turn of the century there were still only about 1,000 members of the AIEE. Since that time not only has there been the phenomenal growth of this Institute, but there have been offshoots from it, such as the Illuminating Engineering Society and the Institute of Radio Engineers which now have memberships in the many thousands.

PROFESSIONAL UNITY

As we look back over the history of organization of the engineering profession and the various parturitions of the profession that have taken place in this first century, we are confronted by the serious question as to where this is leading and whether all of the subdivision has been wise. It is undoubtedly true that civil engineering in its original sense would be much too broad a field today to be encompassed by one technical fraternity. Certainly some subdivision was necessary in order to achieve a true technical community of interest to the members. On the other hand, there are important aspects of the engineering profession such as, for example, professional standards and ethics which are common to all branches and many of us have been asking ourselves in recent years whether there should not be some over-all organization of the profession which would recognize this larger community of interest. Such matters as labor relations and selective service or universal military training legislation in which all engineers have a common interest have made this a vital current topic.

The AIEE has taken a leading position in recognizing this problem and trying to do something about it. Various polls of the membership have been taken in an attempt to learn the sentiment of the members and to steer the policy of the Institute accordingly. Without going into detail about the exact questions submitted and the statistics of the responses, I think it would be a fair summary to say that our membership has strongly favored AIEE participation in an over-all professional-unity organization and specifically that it has preferred a type of over-all organization which would go beyond the mere federation of autonomous technical societies in the sense that individual engineers would be voting as well as dues-paying members.

Backed by this grass-roots sentiment, AIEE sponsored, through Engineers Joint Council (EJC), the organization of an exploratory group consisting of representatives of some 15 of the largest and most influential of the engineering societies, for the purpose of studying the professional organization problem and of recommending a course of action. The Board of Directors now has before it the recommendations of this exploratory group. These recommendations include "first step" proposals to broaden the membership of EJC by adding to its five present member societies perhaps double that number of other engineering societies of generally similar character, and to make other constitutional changes in EJC calculated to effect a closer knit organization on which future unity organization moves could be based. This proposal falls short of the AIEE concept and our immediate question is whether to go along with the exploratory group's recommendations as being at least in the right direction, or to hold out for a more satisfactory "first step."

In any event, I think I can assure you that the new administration, like the one it succeeds, will be very much interested in this professional unity problem and will keep AIEE at the forefront of this movement. At the same time we recognize that the basic interest of the Institute is technical and that the Board should be guided by the policy favored by over 90 per cent of those responding to the 1950 poll as follows:

1. The Board of Directors will work continually for the unification of the profession.
2. The Board of Directors recognizes that the AIEE finds its chief reason for existence in the technical field.
3. The Board of Directors will handle questions on nontechnical affairs as necessary and as they arise, on an emergency basis until through unification they can be handled on a general professional basis.

One aspect of the matter of which we should not lose sight is the fact that the Institute stretches far beyond the borders of this country, with some 1,600 members in Canada, about 250 members in Mexico, and smaller numbers in many other countries. This again emphasizes that technology knows no national boundaries. On the other hand, many of the so-called professional matters have state or national aspects. Any move that we make toward professional unity must bear in mind these somewhat conflicting interests. In this connection, I am glad to welcome the substantial numbers of AIEE members who have crossed national boundaries to attend the Pacific General Meeting and particularly to note that national standards of our neighbors immediately to the north and south fly by the side of our own Stars and Stripes over this rostrum.

Encouragement of Technical Training for Young People

O. W. ESHBACH
FELLOW AIEE

THE GREATEST single factor in providing the proper educational balance among our future leaders is the encouragement of young people to understand the physical world in which we live as well as the human and psychological forces controlling our actions and environment.

Before relating this factor to education, it will be helpful to restate the present situation and cause of concern.

We are preparing to co-operate fully with freedom-loving people in the defense of their homes, nations, and ways of living, against aggressive totalitarian powers. Whether the sacrifices we are making and will make can be justified by the ultimate benefits which will accrue to us is not the sole criterion of judgment. As human beings we have confidence and faith that government by free people is the ultimate solution to world peace. At the same time we are realistic enough to know that wars rarely settle international issues. The social and intellectual development of people so that they may be competent to govern themselves, is essential and requires generations of effort. The expenditure of money is only catalytic to this effort and not the sole solution.

As presently estimated, current needs for engineers are more than twice the maximum long-term trends. As a remedial measure, Dean Eshbach points out the need for training on an intermediary technical level to conserve engineering talent for strictly engineering jobs. To interest qualified young people in engineering as a career, he emphasizes the desirability of providing an elementary foundation in mathematics and science in the high schools.

Because we are an inseparable part of the world-wide struggle, industrially most powerful, and geographically so situated as to be the natural choice as the world's arsenal, we are in danger of overestimating the contribution we are capable of making without permanent injury to ourselves and likewise to our international associates. There are limits to our human, physical, and economic resources. Trying to do the most we can is the primary cause of the manpower shortage, but by no means the only reason for the shortage of engineers.

NEED FOR ENGINEERING

THE NEED FOR engineering services is caused primarily by four factors:

1. The size and complexity of our industrial activity.
2. The rate at which production changes.
3. The advance of scientific and technological knowledge.
4. The effectiveness with which technological talent is used.

If it were possible to measure the effect of these four factors or assign relative indexes to them, we would be much better informed of current and long-term requirements. For example, the four major activities related to the materialistic phases of our civilization would include:

1. The extractive industries, including agriculture.
2. The manufacturing industries producing consumable and capital goods.
3. The service organizations, including our utilities.
4. The purely business activities, including financial, legal, and marketing service.

It is a reasonable assumption that the volumes of activity in each are related to the others in a fairly proportionate manner in such a way that if the growth and change of any one is measured, a guiding index may be established. More specifically, the number of engineers in the United States and industrial output, with the exception of the depression of the 1930's and the war economy of the 1940's, which represent extreme fluctuations, have shown comparable growth in the 20th century. Each is eight to nine times as large today as it was in 1900. Each may be represented by a compounded rate of growth of $4\frac{1}{2}$ per cent per year. Making the debatable assumption that, on the average, supply and demand were in reasonable balance over the half century, we have an index to approximate long-term needs. See Figure 1.

Long-term annual needs are the sum of quantities required for replacement and growth. Replacements due to death and retirement are about $2\frac{1}{2}$ per cent. Growth probably will lie between 2 and $4\frac{1}{2}$ per cent, the lower figure being comparable to the population increase. Thus, except for current fluctuations, the annual need for engineers should be from $4\frac{1}{2}$ to 7 per cent of the present number of 450,000, or roughly 20,250 to 31,500 per year. Since not all graduates pursue engineering, the upper figure easily could be 40,000 graduates per year.

It has been determined with reasonable accuracy that current needs are more than twice the maximum long-term needs. This is due to the current rate of increase of our

Full text of a paper presented at a forum on "The Shortage of Engineers" held during the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952.

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productive economy as exemplified by the rapid changes which took place in both the early 1940's and, more recently, during the last few years. The opposite effect in the 1930's was the cause of a transient oversupply.

We never can expect to meet large transient fluctuations. The nature of the educational process is such that the effect of unanticipated demand produces a supply lagging the need by 4 to 10 years. Thus, if possible, educational facilities and programs must be geared to long-term needs with the universal hope that political and economic fluctuations may be minimized.

WHAT CAN BE DONE?

THIS SUMMARY of the nature of the problem brings us to the subject: what can and may educators in high schools and colleges do about it? It is axiomatic that nothing effective will result without the will to do it, and this depends first upon an understanding of the situation. If we maintain the status quo in education we will not meet minimum annual requirements for technical talent for approximately 20 years.

In making our contribution through education we must recognize what cannot be done and concentrate on what may and should be done.

The first fact to recognize is that science and engineering, like other professions, require both native intelligence and the development of this ability through knowledge and skill. The latter is acquired largely through formal education.

The first question, therefore, is how large an annual supply is possible, assuming effective development through education? There is an approximate answer to this question. The normal distribution curve of our population, obtained by plotting accepted intelligence quotients, shows that less than 11 per cent of those in the high school age group have an intelligence score above 125. This is somewhat comparable to the desired standard for admission to professional study and compares with a qualifying score of 110 for officer material in the military forces. It was also a guiding figure in preparing the selective service deferment tests for college students.

Based on 18 as the normal age for high school graduates, the following table gives the estimated number of 18-year-old males in the country and of both girls and boys being graduated from high school:

End of School Year	Estimate of Males Reaching 18 Years of Age	Estimate of High School Graduates, Male and Female
1952	1,042,000	1,150,000
1953	1,092,000	1,130,000
1954	1,120,000	1,150,000
1955	1,116,000	1,170,000
1956	1,168,000	1,160,000
1957	1,190,000	1,200,000
1958	1,190,000	1,240,000
1959	1,270,000	1,310,000
1960	1,370,000	1,380,000
1961	1,400,000	1,550,000

Assuming an equal distribution of girls and boys in high school, it is apparent that less than 60 per cent of the male population graduates, or approximately 660,000. Of this number over 200,000 may be considered good college material, but less than 100,000 are adequately prepared to study science and engineering.

In competition with others, engineering is represented by approximately 1/3 of the number in major professions and about 1/7 of the total number of all professionally engaged persons. Thus the present number of engineering freshmen, about 35,000, is the best expectancy of good talent which will supply about 17,000 graduates. This is less than the minimum long-term needs and about 1/5 of the current requirements. After graduation, most of these will be in military service.

A POSSIBLE SOLUTION

THE GENERAL but partial solution anticipates answers to the following questions:

1. Can we reduce the number of engineers currently needed?
2. Can the attrition in high school and college be reduced?
3. Can we make better use of the talent we have?
4. Can we increase interest in science and engineering in schools and colleges?

Without analyzing each, the author offers the following answers to these questions as a possible solution.

1. There are two ways in which the number of engineers needed may be reduced. The first is to recognize the limits of our defense efforts, and the second is to recognize the greater need for education and training on an intermediary technical level, thus conserving engineering talent for strictly engineering jobs. To do this our educational system must anticipate the creation of more technical institutes, and the public must de-emphasize the thought that a degree is the only socially acceptable terminal of education.

2. We should like to reduce losses in high school and college. However, not much improvement can be expected for some time.

At present less than 60 per cent of the children who enter the elementary schools graduate from high school. Of the high school group considered of college caliber, the

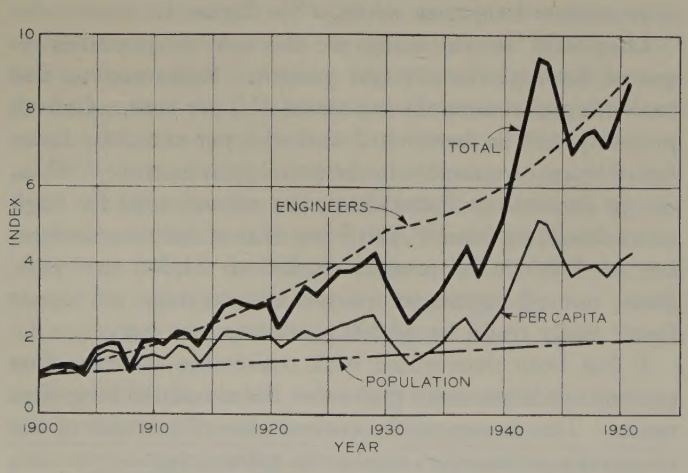

Figure 1. Relative industrial output and number of engineers during the first half of the 20th century

upper third, 20 per cent drop out before graduation and 40 per cent of the remainder go to college. Slightly over half of these finish college.

Attrition in engineering schools has lessened in recent years and is now nearly comparable to that for all college students. Further improvement will depend upon better selection, which will not help the supply. Most improvement may be expected from good counselling, better intellectual motivation in home and school, and improved financial resources. The primary cause of the avoidable attrition in college, however, is lack of intellectual interest or motivation rather than inability to pay the cost.

3. In the meantime it is necessary that the best use be made of engineering and scientific talent. This will be accomplished in industry only in so far as management is conscious of the impossibility of materially adding to its technical force. It involves initiative on the part of every organization. Should war become more imminent or the situation more serious, we again may expect plans within industry and educational institutions for short specialized courses. This procedure has very little to contribute to the long-term supply of broadly educated engineers.

It appears that the most serious waste of engineering talent is resulting from the assignment of graduates to ordinary military functions after their induction into the armed services. It must be realized that the armed services need some engineering talent but at the present stage it would seem we could well afford either to reduce the number of people in service or declare a temporary moratorium on the drafting of any technical talent for this purpose. The present practices are inimical to the national safety and cannot contribute best to the defense of our allies.

4. It is not likely that much can be accomplished immediately by a campaign to interest present high school students in studying science and engineering; an increase in the attrition rate in college probably would be one of the inevitable results. The primary reason for this assumption is the apparent insufficient interest in scientific subjects in high school. It is reported that in the last half century the percentage of students studying physics and chemistry has decreased from 22 to $5^1/_2$ per cent and from 10 to $7^1/_2$ per cent, respectively. This does not mean that there are not more students studying physics and chemistry, but rather that the percentage of interest has shown a sharp decline.

The high schools should not be unduly criticized, however. On the whole, the United States has the best system of secondary education in the world. A high school student can get an excellent preparation for college. It is true that greater rewards in industry have attracted those most competent to inspire interest in scientific subjects. In a few instances industry has recognized the need for making teaching positions in science more attractive by providing means for supplementary income to science teachers. The heart of the problem, however, is that neither the public nor, in general, educators in institutions of higher learning appreciate that a broad fundamental education must include a foundation to understand the nature of our physical world.

SCIENCE IN THE HIGH SCHOOL

There is a widespread feeling among parents and students that technical studies are narrowing and, in their specialization, too exacting in discipline. The intellectual laxity which has been allowed to creep into our educational system has not produced, and cannot be expected to produce, an adequate supply of properly trained college freshmen for the needs of our future civilization. Contrary to opinion, relative financial rewards are not nearly as serious in their effect on engineering enrollments as the unwillingness of students to develop latent intellectual capacities.

A striking manifestation of the quality of preparedness for college are the results shown by the selective service college qualification test. It is no accident that 75 per cent of the freshmen engineers and scientists qualified either by score or standing in class for draft deferment. No other group equalled this record. The colleges were not responsible for the results. It is distinctly a reflection of the seriousness and breadth in preparation of prospective engineering and scientific students in high school.

It is not unreasonable to anticipate an elementary foundation in mathematics and science in the concept of broad preparation for college study. A vigorous national campaign emphasizing this deficiency would not seriously hurt anyone's education, but would give to each high school graduate a far greater flexibility in the choice of professional study at a time when he is best able to make this choice. This means that the counselling problem in high school must begin with the freshman class. The study of mathematics and physical science in high school by no means precludes the selection of a liberal arts program in college but indifference to it definitely excludes the possibility of entering the field of engineering and science.

Railroads Report 900% Power Gain

The electrical generating capacity of the nation's railroads has increased 900 per cent in the past 10 years, according to a study revealed by the General Electric Company. The railroads now have electric machinery capable of generating 18 million kw where 10 years ago they scarcely had enough to generate 2 million kw. This increase in the use of electric generators as well as motors on the railroads results from the increasing use of the electric drive on diesel-electric locomotives. Better than half of the railroads' locomotive fleet are now diesel-electrics on which the power plants are capable of producing an average of 1,200 horsepower. The combined horsepower of the diesel-electrics comes to approximately 18 million kw. With the railroads a little better than half dieselized now, it is expected that the generating capacity will nearly double as the railroads approach full dieselization of locomotives in the next 5 years.

Measurements on New Transformer Insulation

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MEASUREMENTS OF THE power factor and resistance characteristics of transformer insulation are being used increasingly for the control of quality in the factory. The usefulness of these measurements is based on the fact that they are affected by any ionizable impurity such as water, low molecular weight acids from oil deterioration, soluble salts, and other contaminants. In the factory, the principal use for these measurements is the detection of moisture. This moisture has the effect of increasing the insulation power factor, decreasing the insulation resistance, and decreasing the dielectric absorption effect.

There are other factors besides moisture which affect these dielectric measurements and must be considered in their evaluation. Different insulating materials have inherently different loss and resistance characteristics. The measured values on the assembled transformer will depend upon the way in which these materials are combined. The inherent values of power factor and insulation resistance should not be considered a direct index of quality. These measurements are only indirectly useful by detecting harmful contaminants.

In order to evaluate the effect of moisture on the dielectric strength and measurements, an experimental study was made using oil-impregnated pressboard sheets. Three types of breakdown tests were made: negative polarity impulse tests; 60-cycle 1-minute step-by-step tests; and 60-cycle 7-hour step-by-step tests at a temperature of 90 degrees centigrade.

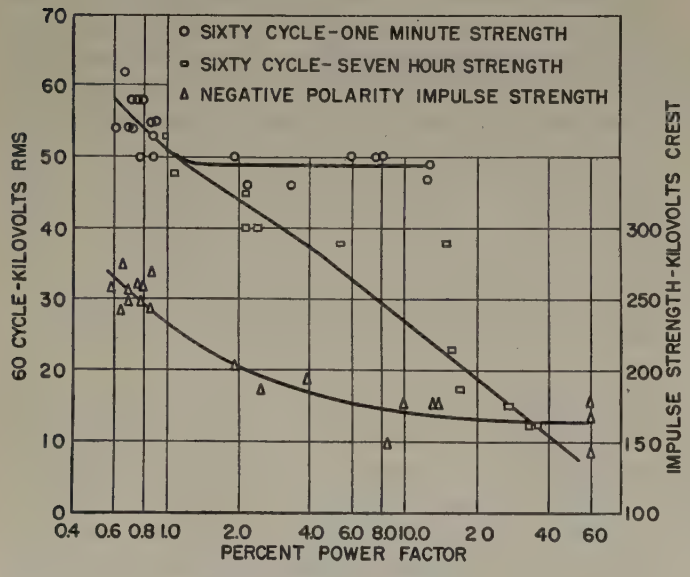

Figure 1. Puncture strength of oil-impregnated pressboard

Figure 1 shows the strength of the pressboard samples as influenced by moisture. The power factor plotted for the 7-hour tests is that measured at 90 degrees centigrade. The results of these tests showed a correlation between all of the various dielectric measurements, moisture content, and dielectric strength.

Table I. Per-Cent Power Factor of Power Transformers

	No TCUL*		With TCUL*	
	Median	98 Per Cent Less Than	Median	98 Per Cent Less Than
Oil-filled				
69 kv and up				
2,000 kva and up	0.45	0.64	0.57	0.96
Less than 2,000 kva	0.45	0.75		
Less than 69 kv				
2,000 kva and up	0.50	0.78	0.62	1.02
Less than 2,000 kva	0.61	0.90		
Inerteen-filled	2.4	3.7		
Dry-type	1.5	17.0		

* Tap changing under load

All values have been corrected to 20 degrees centigrade.

Power factor measurements on a number of power transformers are summarized in Table I. The Inerteen-filled and dry-type power transformers illustrate lines with inherently higher power factors.

Both power factor and insulation resistance measurements have been found advantageous under certain circumstances. Power factor measurements have the advantage of being dimensionless, and vary little with design and rating if the same kind of insulation and general construction is used. For this reason, the power factor is useful when an evaluation must be made from a single measurement. Single measurements of insulation resistance are of limited value, but a series of measurements are more responsive than power factor in detecting changes in the insulation.

These dielectric measurements are used extensively in the factory. Power factor measurements are used in the investigation of new materials and in controlling the quality of insulating materials used in production. Insulation resistance measurements are used for determining when a transformer is completely dry during the drying process. Power factor measurements are used for a final over-all check on the completed transformer.

These measurements are very useful in controlling the insulation quality if they are interpreted properly. Consideration must be given to the various factors which will affect these measurements and to the effect of these factors on the dielectric strength.

Digest of paper 52-159, "Dielectric Measurements on New Power Transformer Insulation," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Radio Noise in Relation to the Design of High-Voltage Transmission Lines

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Radio noise has been a major concern in high-voltage transmission-line design. The Bonneville Power Administration began a study of the situation during the war emergency. This article is a report on the continuation of that research.

THE MAJOR REASON for the study of radio noise on high-voltage lines is elimination of interference in domestic amplitude-modulated radio receivers. To accomplish this end, the user of high-voltage equipment must know how to specify adequate but not unnecessarily expensive equipment. Complete information of this nature is not yet generally available.

In usual laboratory practice, "generated" radio-frequency voltages are measured in microvolts by means of a direct capacitive coupling to the equipment under test. In service, radio disturbances from high-voltage lines are caused by coupling through space of propagated waves either directly to a receiving antenna or with an intermediate carrier such as a low-voltage distribution system. The magnitude of this "radiated" field strength, usually measured in microvolts per meter, cannot be evaluated from the microvolts measured in the laboratory. Therefore, while laboratory tests are useful in determining relative intensities generated, these data do not inform the user of levels that are adequate to eliminate disturbances in domestic receivers.

Lower voltage transmission and distribution pin-type insulated lines are potential sources of more radio interference than are high-voltage suspension insulated lines. Where these lines parallel or cross residence service lines with close separation, induced coupling carries interference into homes. Another potential source of severe radio noise, and probably one of the most common, is due to loose or improperly placed hardware on the lower voltage wood pole lines. Not only is this one of the first places to investigate complaints, but static discharges from this source radiate with much greater energy, and therefore they are more severe than corona discharges.

It has been common practice on the Bonneville system to use 1.108-inch-diameter steel-reinforced aluminum cable Drake conductor for 230-kv lines. Experience, both close to broadcasting stations as well as remote from them, indicates that this conductor is satisfactory and possibly a little conservative with reference to adequate radio noise levels. For the first few months after being placed in service, these conductors are usually in continuous audible corona in fair weather but do not involve more complaints than after they have aged. In the absence of standards and for design purposes, the Bonneville Power Administration has adopted a level which appears adequate as a basis for future installations. This level is a fair weather field strength of 15 microvolts per meter at a horizontal distance of 200 feet from the nearest conductor of the transmission line at midspan. This level is increased by 10–50 times in inclement weather, which has not been of sufficient severity to provoke complaints. The distance of 200 feet was chosen in order to be assured that the level measured remained outside that in which the electrostatic field predominates. Actually, the electrostatic field practically disappears within 150 feet.

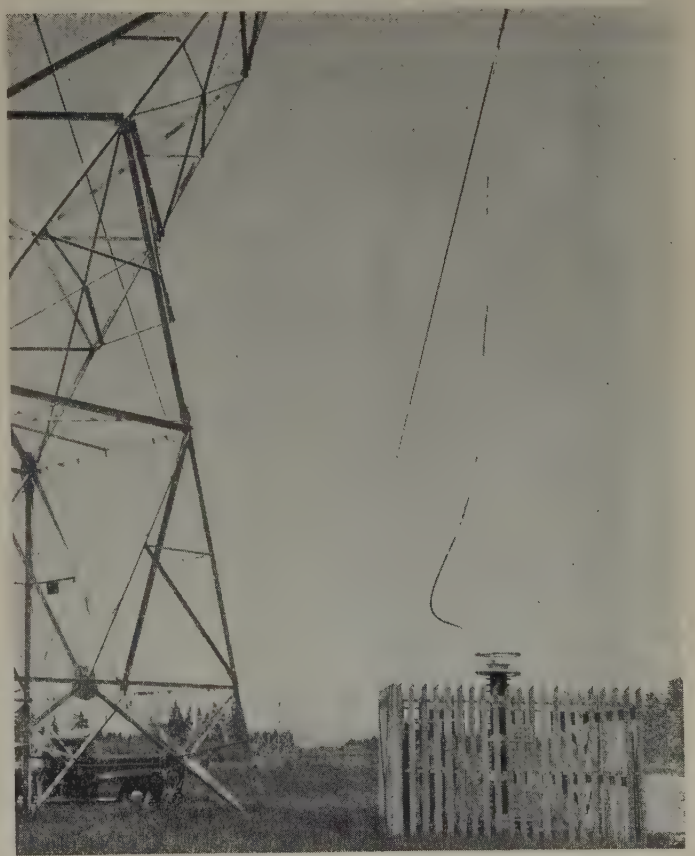

Figure 1. Capacitative coupled circuit for recording radio-frequency voltages, Tower 41, Ross-Longview 230-kv line

Condensed text of paper 52-106 "Investigation of Radio Noise as it Pertains to the Design of High-Voltage Transmission Lines," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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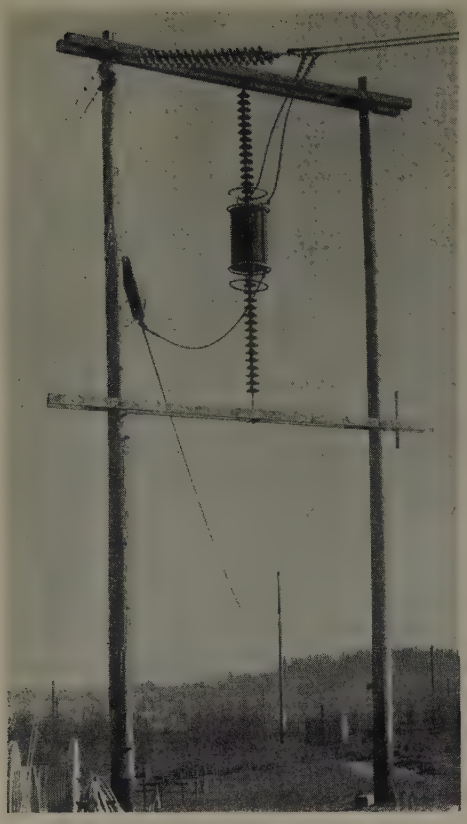

Figure 2. 400-foot single-conductor test span

EXTENT OF THE STUDY

This investigation of radio noise was divided into three groups: 1. laboratory tests, 2. tests on 230-kv lines in service, and 3. tests on a 400-foot span single conductor. The laboratory tests were made at 1,000 kc, while the two latter tests were made at 820 kc due to the proximity of a radio station broadcasting near 1,000 kc. For comparative purposes, all tests were made with Ferris Radio Noise and Field Intensity Meters of the same type. All readings are given in peak values as measured by the response time characteristics of the meter.

There were two major objectives in conducting service tests to supplement data obtained in the laboratory: (1) to correlate generated radio-frequency voltages on transmission lines and corresponding field strengths that may reach radio antennas in the vicinity of transmission lines, and (2) to determine what correlation exists between generated radio-frequency voltages as measured by laboratory tests and that existing on a transmission line.

Capacitance coupling to one conductor of a transmission line in service, shown in Figure 1, provided data directly comparable to laboratory methods. A 400-foot single conductor test span terminated in its surge impedance and also equipped with a capacitive coupled circuit is shown in Figure 2. At the entrance to the test area, a radio-frequency filter of the type commonly used with carrier equipment and tuned to 820 kc was used to prevent disturbances of near this frequency from interchanging between the test area and the service line.

LABORATORY TESTS

Addition of Radio Noise From Multiple Sources. As radio-frequency voltages originating on insulators and hardware in service may be generated from these several sources simultaneously, tests were made to see how these levels added to produce the over-all level. Five 16-unit strings of conventional $5^{3}/_{4}$- by 10-inch insulators with conductor clamps were assembled with a noise-free conductor, a 2-inch tube, so that all strings could be excited simultaneously or in any combination by removal of any of the strings and substitution of the clamps. Figure 3 compares the radio noise as measured from 1. a single 16-unit string, the average of 5 strings tested separately, 2. five strings in parallel, 3. one string with a conventional conductor clamp, and 4. a conductor clamp only. Within the range of variation that is common in radio noise tests, the general level of the five strings in parallel is no different from that of any one of the strings tested separately. Also the average of the five strings tested with noise-free clamps is substantially the same as the five strings tested with conventional clamps.

A smooth 1-inch diameter tube was sprayed throughout its length with water. Since the water spray was not maintained continuously, the size of the drops changed due to the electrostatic stress as voltage was increased, and therefore the results are probably not strictly accurate; however, they are indicative. Voltage was increased

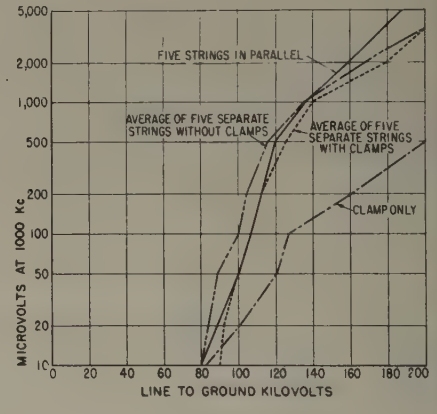

Figure 3. Radio-frequency voltage from single-and multiple-insulator strings

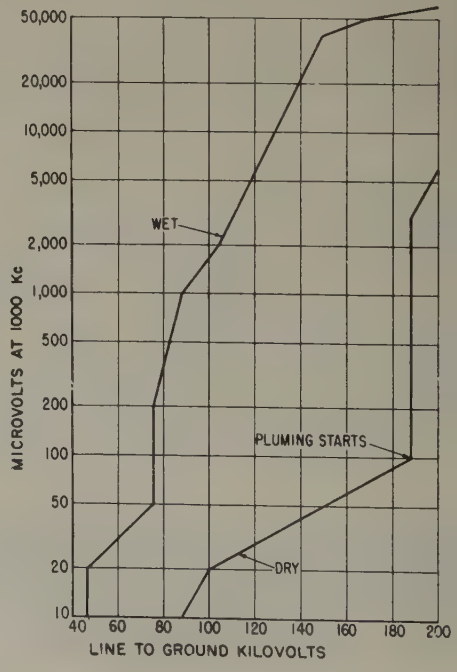

Figure 4. Radio-quency voltage from short length of conductor

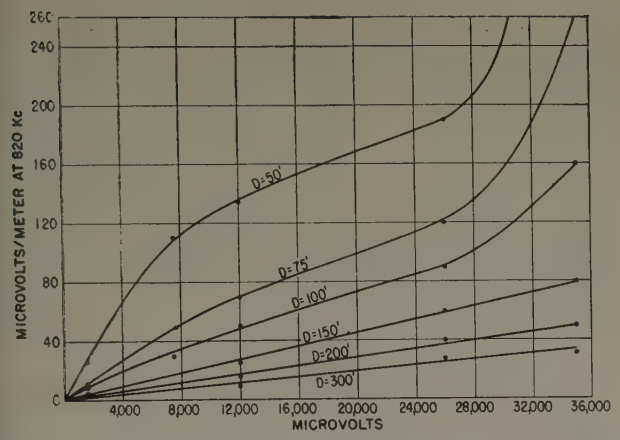

Figure 5. Correlation of generated radio-frequency voltages and radiated field strengths

rather rapidly and inspection of the tube after test showed a considerable amount of water still on the under surface. Figure 4 shows that the noise level with the conductor wet is 100 to 500 times as severe as with the conductor dry for voltages up to 180 kv. At nearly 190 kv, the dry conductor abruptly broke into plumes and the radio noise increased 30 to 50 times the glow level without any appreciable change in applied voltage. Water drops on a conductor generate more radio-frequency voltage than do the irregularities that may exist on a conductor in service.

INSULATORS AND CLAMPS

Due to the nonuniformity of normal voltage distribution across an insulator string, only the first one or two units at the line end are ever under enough continuous voltage to be at or near the corona level. At the higher voltages, corona streamers on insulators may well be reduced when the insulators are wet. This occurs because rain provides a partially conducting surface at the overstressed area. There seems to be no reason why insulators should not be operated in continuous corona as long as losses, radio noise, and unbalanced voltage distribution across the insulator string do not become excessive.

Comparison of Figures 3 and 4 shows that in the higher voltage range corona plumes due to water create considerably higher radio-frequency voltages than corona streamers on insulators.

TESTS ON LINES IN SERVICE

Generated Radio-Frequency Voltages Versus Radiated Radio-Frequency Field Strengths. On two different occasions, data were obtained as a rainstorm passed over the test area on the Ross-Longview line at Tower 41. During the first storm, rainfall was extremely heavy and simultaneous readings were taken with the coupled circuit and with the antenna. The data are plotted in Figure 5 and show that the field strengths are correlated directly to the radio frequency generated on the transmission line. The second rainstorm was recorded automatically. The coupled circuit indicated some instantaneous values that reached 100,000 microvolts, but of very short duration. Records taken over a period of nearly a month indicate no appreciable difference between the generated radio-frequency levels at tower and at midspan.

Effect of Noise Generated at a Localized Point. To observe the radio noise generated by insulators and hardware wet versus dry on a line in service, the effect of rain was simulated by placing a container of water on Tower 41 with a hose so directed that water could flow over the insulator string onto the conductor. After obtaining readings by both the antenna directly under the conductor and the coupled circuit, a stream of water was directed over the insulators to the extent that water was dripping from the energized conductor for about 5 feet on each side of the point of suspension. Water also ran down the conductor to the coupling capacitor and was dripping from the shield rings and from the capacitor terminals. Violent corona plumes from a myriad of points within the wet area were evident audibly. Yet, other than to become somewhat unsteady, both meters recorded no substantial increase in the radio-frequency voltage over the fair weather levels. This indicates a performance in service not duplicated in laboratory tests. Under similar conditions in the laboratory, the level with the coupled circuit increased ten times.

This observation led to the conjecture that radio noise generated at isolated points along the line, such as at the towers, is relatively unimportant in the over-all performance of the line. On this premise, shielding insulators and hardware with grading rings are ineffective for reducing the radio noise even though the insulators and hardware may be in continuous corona. Grading rings may effect some reduction in corona losses in fair weather, but it is questionable if the savings ever will exceed the cost. This test indicates that the suppression of corona on insulators, suspension clamps, armor rod clamps, vibration dampers,

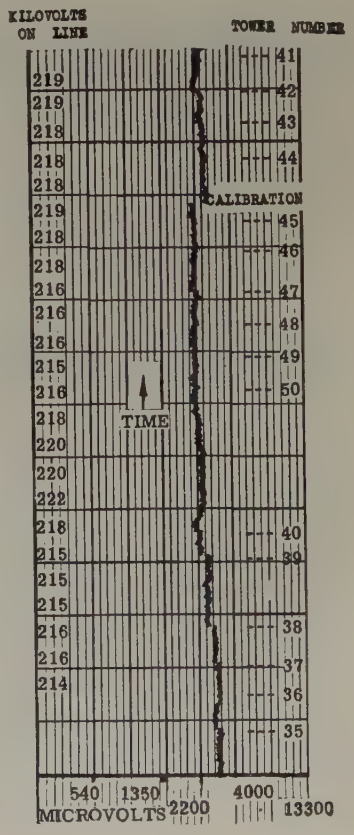

Figure 6. Effect of point sources on the radio-frequency voltage level of transmission line

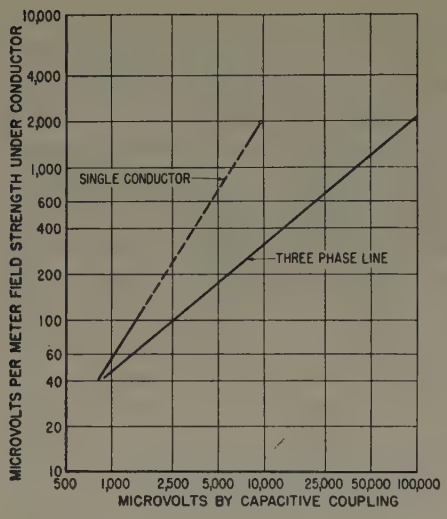

Figure 7. Relation of generated radio-frequency voltages to field strengths for single-conductor and 3-phase line

Table I. Effect of Conductor Height

Conductor* Height, Feet	Coupled Circuit, Millivolts	Field Strengths, Millivolts per Meter for D** 0	25	50	100	200
30	4,500	480	320	40	24	12
26	4,500	480	340	38	24	12
20	4,500	600	320	36	22	12
14	4,500	850	220	30	20	12

* Steel-reinforced aluminum cable Pheasant conductor $E=201$ kv L-G

** D = horizontal distance from conductor in feet

Table II. Effect of Ground Wire

Distance From Conductor,* Feet	Field Strengths, Millivolts Per Meter: No Ground Wire H**=29	No Ground Wire H=14	Ground Wire H=29 S†=10	Ground Wire H=14 S=10
0	2,000	4,000	2,500	5,000
25	700	1,000	1,000	1,000
50	160	200	250	200
100	66	50	50	38
200	26	22	16	10

* Steel-reinforced aluminum cable Pheasant conductor $E=200$ kv, L-G

** H = conductor height, feet

† S = conductor to ground wire separation, feet

and the like will not improve the over-all radio noise characteristics of a line to any appreciable degree.

In order to verify the preceding observation, Tower 41, as well as nine consecutive towers to the north and six to the south of Tower 41, were equipped with 2-foot lengths of greased barbed wire. It was found that grease on the barbs contributed to the size of the corona plumes. Several days were required to install the barbed wire and records taken during this interval show usual daily variation and are not indicative of any noticeable change in noise level due to the barbed wire corona generators. All 16 barbed wires were removed within a 7-hour period, during which time the continuous record of Figure 6 was obtained with the coupled circuit. During the removal of the barbed wires, the change in the recorded radio-fre-frequency level was from 2,900 to 2,300 microvolts. Definite small jogs downward occurred at the instant some of the barbed wires were removed. The offset between Towers 44 and 45 was due to calibration adjustment of the meter. The total change due to removal of the corona plumes at all towers in 3 miles of line was considerably less than the daily variation of two to three times the minimum level of the line in fair weather.

TESTS ON 400-FOOT SPAN

Single-Conductor Versus 3-Phase Tests. Figure 7 illustrates the comparison of generated radio-frequency voltages with field strengths directly under the steel-reinforced aluminum cable Drake conductor at midspan for the single-conductor test line and for the Ross-Longview 3-phase line. The data represent an accumulation of results in all weather and are not continuous beyond the plotted lines. Also, on the test conductor, as is shown later, the radio-frequency field strength is not dependent on rain intensity as it is for the 3-phase line. Only the solid line of the test conductor data of Figure 7 was obtained by test. The dashed line represents the interval between fair and foul weather levels within which no readings occurred. The minimum levels represent the lowest fair weather data recorded, and the highest points represent the highest foul weather data obtained during more than a year of testing. The curves converge toward the lower fair weather levels, and so in this range there is not much difference between the single-conductor and 3-phase field strengths for the same level of generated radio-frequency voltage. In foul weather, shown by the upper range of the curves, considerable diversity is apparent, yet from all available data, the maximum recorded field strength of 2,000 microvolts per meter directly under the conductor was the same for the 3-phase as for the single-conductor tests. These equal field strengths were obtained when the generated radio-frequency voltages, as measured by the coupled circuit, were ten times as great on the 3-phase line as they were on the single test conductor. The data show that the generated radio-frequency voltage, and therefore corona, may be considerably higher on 3-phase lines than on a single conductor, which is to be expected from the established theories of voltage gradients. These data collected in fair and extreme foul weather only, indicate that field strengths on the test conductor obtained by antenna pickup are indicative of conditions in service, but levels obtained by capacitive coupling are not.

Effect of Conductor Height. To determine the effect of conductor height on radio-frequency field strengths, data were obtained with the test conductor energized continuously while the conductor was raised and lowered at midspan. Results are given in Table I, which is a typical run of several repeat tests. While the conductor was lowered from 30 to 14 feet, the coupled circuit indicated no change in the generated radio-frequency voltage but directly under the conductor the antenna pickup indicated an increase of more than double. At all distances of 25 to 100 feet from the conductor, the noise level decreased as the conductor was lowered and at 200 feet there was no change. Curves of these data cross each other. These results may be contrary to the usual conception, but

they are not contrary to theory and do not appear difficult to understand. They also substantiate the earlier reported observations of the change in field strength due to change in conductor separation. When the conductor is brought closer to ground, the audible corona, and therefore undoubtedly the losses, increase. Likewise, the field intensity directly under the conductor increases. However, the closer proximity to ground changes the configuration of the dielectric field so that a greater voltage gradient exists in the field between conductor and ground, but a less intense field of high-frequency wave propagation into space.

Effect of Ground Wire. A ground wire was erected in the test span above the energized conductor to observe its effect on the radio-frequency field strength. The performance with a ground wire may not be directly comparable to energized conductors in horizontal separation, but the data are indicative of the change in the radio-frequency field. Table II compares the relative levels of one of several tests with the antenna pickup for two different conductor heights. The ground wire separation in both cases was 10 feet, which is considerably less than usually obtains in service. As in Table I, curves of the data of Table II cross each other. It is apparent that the presence of the ground wire, as well as the height of conductor above ground, influences the radio-frequency field around the conductor so that a general relation between generated radio-frequency voltages and the associated field strengths must include the parameters that control the configuration of the dielectric field. These results may be somewhat amplified because of the close conductor separation.

Effect of Intensity of Rain on Short Versus Long Lines. A difference between results obtained on a short length of line versus that on a long line in service n inclement weather is illustrated in Figure 8. At the time of this test, steel-reinforced aluminum cable Pheasant conductor was suspended in the test span and it was excited at 173 kv line-to-ground. Ferris meters with antennas for recording field strengths were located directly under midspan of the test line as well as directly under one of the 230-kv lines near Troutdale Substation. The distance between the two meter locations was about 1/3 mile. Figure 8*A* illustrates the field strength from the test span which rose fairly rapidly as rain started and held an almost uniformly constant level thereafter for a considerable period of time after the rain had stopped. In Figure 8*B*, the level on the transmission line indicates a considerable variation after the rainfall started. The data of Figure 8*C* were obtained from a weather station about a mile from the test area. At the weather station, rain apparently started shortly after that recorded at the test area, indicating that the storm may have reached the test area first and traveled toward the weather station. Duration of the rainfall at the weather station coincides to a fair degree with the field strengths from the transmission line, but other than at the start of rainfall, has no correlation to the level of the test span.

Coupling Into Distribution Lines. The summation of the test data indicates that the greatest hazard from radio noise originating on high-voltage systems is caused by coupling into distribution systems rather than by direct coupling into domestic antennas. While there are some exceptions, such as in areas where the signal strength of broadcasting stations is relatively low, there is fair reason to believe that most troubles are spread over a wide area through the medium of the distribution system. If the coupling between high-voltage and distribution lines can be reduced or the radio-frequency energy otherwise prevented from radiating on the distribution system, it should be possible to tolerate higher levels on the high-voltage systems and thereby in some applications effect a considerable reduction in first cost.

There are several possible methods of reducing the radio noise coupled into distribution systems, such as: 1. shield wires, 2. choke coils, and 3. shunt capacitors. Of these three, shunt capacitors on the distribution line serve the

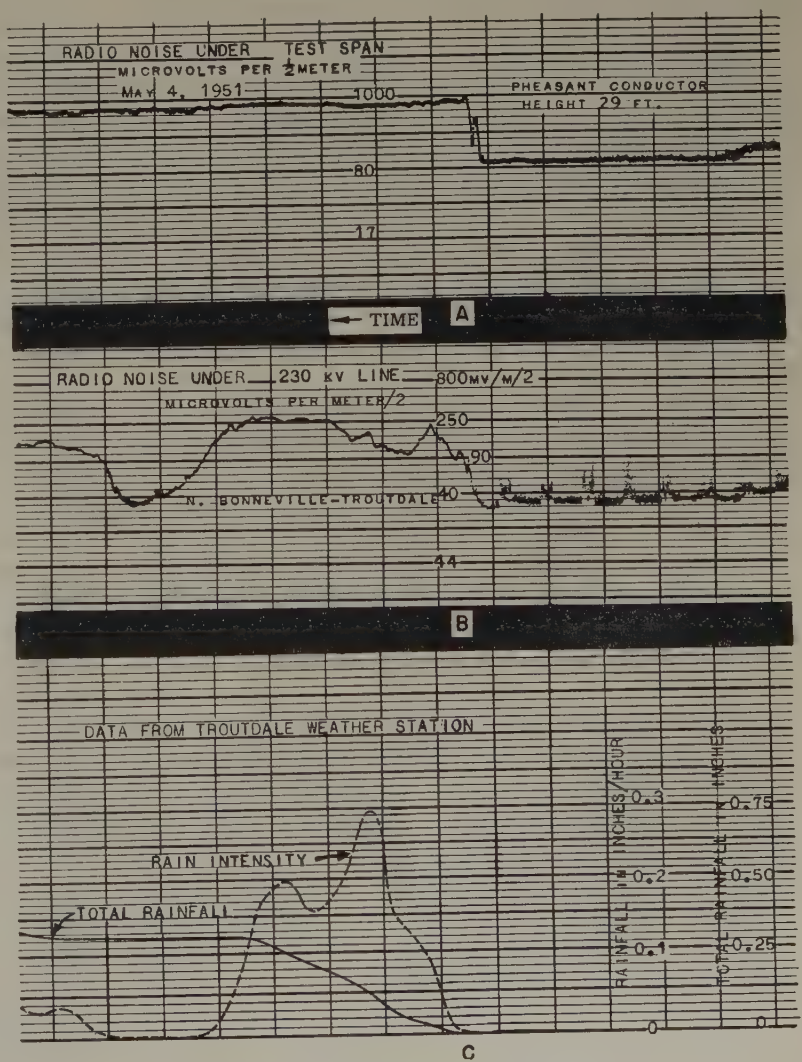

Figure 8. Influence of rain intensity

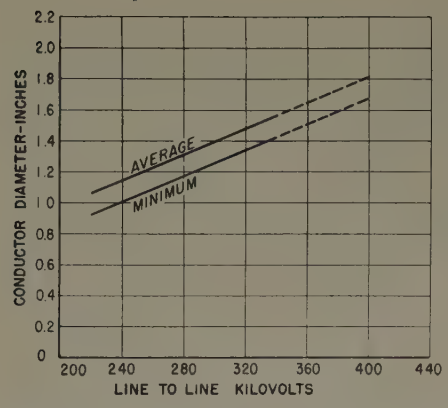

Figure 9. Steel-reinforced aluminum cable conductor diameters for high-voltage lines

additional advantage of power factor improvement. Shield wires might be installed either on the distribution system or on the high-voltage lines. Choke coils on the distribution line might be located on both sides of a crossing where radio-frequency coupling occurs. Further study of this question probably will require an elaborate test installation since there is no known location on the Bonneville system at the present time where a relatively high interference level can be expected by coupling in any weather. It seems probable, however, that a considerable transfer of energy is necessary to raise the level of a distribution system an appreciable amount. This involves such factors as separation between conductors of the two systems, angle at which the lines cross, or length of parallel rights of way.

CONDUCTOR DIAMETERS FOR HIGH-VOLTAGE LINES

One of the major objectives of the investigation was the determination of adequate conductor diameters for the higher transmission voltages. Considerable data have been published of this nature both for single and multiple conductors. The question is complicated by the wide diversity of results and the multiplicity of factors involved. Radio noise measurements are not so concise that curves may be plotted which accurately indicate performance that may be expected in service. Grease, such as that on new conductors as shipped from the factory, results in unusually high levels on new lines, which reduce to considerably lower levels within a year as the grease disappears with age and the conductor attains a coating of contamination. This, as well as disturbing the contamination coating during test, adds to the diversity of the results. The levels in rain are so much higher than those in fair weather that it seems improbable that age or surface condition of the conductor make much difference in the rain.

The real criterion for determining the maximum voltage that should be satisfactory for a given conductor diameter is the radio-frequency level in extremely heavy rain. Yet, data taken in the rain vary over such a wide range that it does not seem practical to use them for design purposes. The fair weather data, although also susceptible to considerable diversity, are far more consistent than are the rain data. But radio interference from high-voltage lines is not a common problem in fair weather, and so only fair weather data may not be a good criterion for transmission-line design.

If lines should be designed on the basis of fair weather only, past practice has been too conservative. If lines should be designed on the basis of extreme foul weather levels, present practice is within an acceptable range and might even be a little more conservative than is necessary in many installations. Since extreme foul weather exists in most localities for considerably less than one per cent of the time and if considerable expenditure is required to assure absolute freedom from radio interference during this interval, the prevention well may be far more expensive than a cure.

The recommended conductor sizes given in Figure 9 are derived from the test data and experience on the 230-kv Bonneville system. The average curve is based on the premise that the conductors now in use on the Bonneville system constitute good practice with reference to radio noise levels. The slope of the curve is obtained by the relative performance tests of other conductors with respect to the Drake. The minimum levels are based on experience with the 1-inch conductor as well as the relative performance of all conductors tested in this investigation. We do not believe that adherence to the minimum levels constitutes good general practice, because of system losses and limited transmission capability, but there is ample evidence in the test data to indicate that radio noise should not be excessive in most cases if it is found necessary to apply the maximum possible voltage to a conductor of minimum acceptable diameter. It is possible that even smaller diameters may be acceptable on lines equipped with continuous ground wires, or where conductor height and separation are reduced to a minimum, because of the greater rate of attenuation of the field pattern. Some advantage may be obtained on lines near residences by reducing the conductor separation, or by adding ground wires, or both.

As a result of this investigation, the Bonneville Power Administration is contemplating the installation of autotransformers to increase transmission voltages from 230 to 295 kv on some major lines equipped with the steel-reinforced aluminum cable Pheasant conductor and to transmit power at 345 kv on lines equipped with steel-reinforced aluminum cable Falcon conductor.

CONCLUSIONS

1. Minimum conductor diameters for the higher voltages having tolerable radio interference levels for usual applications are about 0.95 inch for 230 kv, 1.25 inch for 300 kv, and 1.45 inch for 345 kv. Other system limitations usually will dictate the use of larger conductors. Ice melting favors the smaller conductors.

2. Direct radiation from a transmission line usually will not produce objectionable interference in radios having antennas located 200 feet or more from the line, although this is dependent upon the signal strength of the broadcasting station. Radio noise coupled into low-voltage lines crossing or paralleling a high-voltage line may be carried for a considerable distance, thereby spreading over a wide area the disturbance which originates on the high-voltage line.

3. Of the three potential sources of radio noise, the conductor is the only serious offender, and preventive

measures taken with respect to insulators and hardware are generally ineffective.

4. The noise level of a transmission line is greatly affected by rain intensity. In this investigation, the light rain level was about 8 times the fair weather level, and this increased to 30 or more times as the rain intensity increased.

5. Drops of water on a conductor are a worse offender in generating radio noise than irregularities or sharp projections. In fact, conductor stranding and surface irregularities are not important in the generation of radio noise.

6. Presence of ground wires and reduced conductor separation and height changes the configuration of the predominant field pattern so that the intensity of the radio-frequency field directly under the conductor is increased, but the rate of attenuation with distance from the conductor is also increased so that the field pattern is confined to a smaller area.

7. Radio-frequency voltages generated from several independent sources at a single location are not additive as the rms of the individual levels. In laboratory tests using short lengths of conductor, the noise level determined by the worst offender determines the level generated at the location from a multiplicity of sources.

8. Radio noise performance of high-voltage equipment in service is not simulated by the usual laboratory tests using capacitive-coupled detector circuits.

Possible Industrial Hazards in the Use of Microwave Radiation

H. M. HINES J. E. RANDALL

With the advance of electronic equipment into the microwave region and the increased use of these high frequencies in the medical field, studies have been inaugurated to ascertain their effects on living organisms. Findings of experiments on laboratory animals indicate that these waves heat internal organs dangerously upon long irradiation.

CURRENT INTEREST in the biologic effects of high-frequency electromagnetic waves has been stimulated by their increased use as a therapeutic agent in medicine and in radar communication. Numerous reports have appeared concerning the effects of various frequencies of electromagnetic waves upon living organisms. Much speculation has been advanced as to whether the biologic effects of exposure to electromagnetic waves are to be attributed to temperature increases resulting from the absorption of this form of energy or in part to effects other than those due to thermal changes. In experiments carried out in the authors' laboratory no crucial evidence was found for biological effects due to causes other than those related to temperature change. However, it should be pointed out that it is difficult, in many instances, to rule out completely the possibility of athermal effects. It is believed that the potential hazards that may arise from exposure to high-frequency electromagnetic waves are due either directly or indirectly to increases in temperature resulting from the absorption of this form of energy.

Under ordinary conditions the temperature of a normal resting human subject is remarkably constant. It is interesting to note that temperature increases of as little as 5 degrees centigrade above the normal or optimal level, if maintained for sufficient time, may be injurious or even lethal. Thus the human body functions best at a temperature only slightly below that which would be injurious or lethal. In fevers the temperature increases come dangerously close to the upper limit of thermal tolerance. It is reasonable to expect that the maintenance of a constant temperature so close to one which would be either injurious or lethal would require a very effective mechanism for regulating the balance between heat production on the one hand and heat loss on the other. The operation of the factors which regulate heat loss from living subjects are far more complex than those concerned with heat loss from inanimate material. Such mechanisms are numerous and complex and can be sketched only briefly in this article. The human subject is equipped with mechanisms which serve either to increase or decrease heat loss. Such mechanisms operate either in local areas of the body or throughout the organism as a whole. Likewise, mechanisms exist which operate in such a manner either to increase or decrease heat production. The various mechanisms are coordinated by a heat-regulating center in the brain which operates somewhat like a thermostat.

The circulating blood acts as an effective distributor of heat in the body somewhat analogous to the circulation of

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water in the radiator of an automobile. In the case of an animal, however, mechanisms exist for controlling the diameter of the blood vessels and thereby regulating the volume and velocity of blood flow. Because of this and other mechanisms, the temperatures in different parts of the body are ordinarily maintained within rather narrow limits. However, not all areas of the body are equally well equipped with mechanisms for regulating their temperatures by means of changes in blood flow. This is particularly true for the chambers of the eye and the hollow viscera, such as the gall bladder, urinary bladder, and lumen of the gastrointestinal tract. These areas are relatively avascular and largely devoid of effective mechanisms for regulating their temperature.

Although the precise temperature level at which injurious effects are first to be noted has not been determined for all tissues, it is known that it varies for different tissues. Thus, the testes undergo degenerative changes if maintained for a considerable period of time at a temperature equal to that found in the abdominal cavity. Nature protects these structures against such thermal damage by causing them to descend to the scrotum during development where lower temperatures ordinarily prevail.

The amount of temperature increase occurring in living tissues and in the organism as a whole during exposure to high-frequency electromagnetic waves depends upon at least four factors: 1. Specific area or areas of the body which are exposed to irradiation and the efficacy of their mechanisms for heat elimination. 2. Intensity or field strength of the radiation energy. 3. Duration of the exposure. 4 . Specific frequency or wavelength of the radiations.

LABORATORY EXPERIMENTS

Exposure to high-energy-intensity outputs of electromagnetic waves for only a few seconds may be lethal to many species of laboratory animals (Table I). It is to be pointed out that the column of figures in the table headed by "watts" refers to the strength of the total field output and that any one animal absorbed only a portion of this energy. Animals which survived short periods of exposure showed at autopsy extensive and widespread histopathologic damage to the various organs and tissues. In these experiments the lethal effects are attributed to a generalized increase in body temperature which led to a thermal paralysis of the respiratory center. Cessation of respiration was followed by oxygen lack in the tissues which resulted in circulatory collapse and death (Figure 1). The physiologic changes preceding the onset of respiratory paralysis are typical of the responses which the body makes to an intense, overwhelming, and painful environmental situation. These findings suggest certain first-aid measures that should be employed in the treatment of human subjects accidentally exposed to high intensities of electromagnetic waves. These include artificial respiration, oxygen administration, and measures which provide for a rapid cooling of the body.

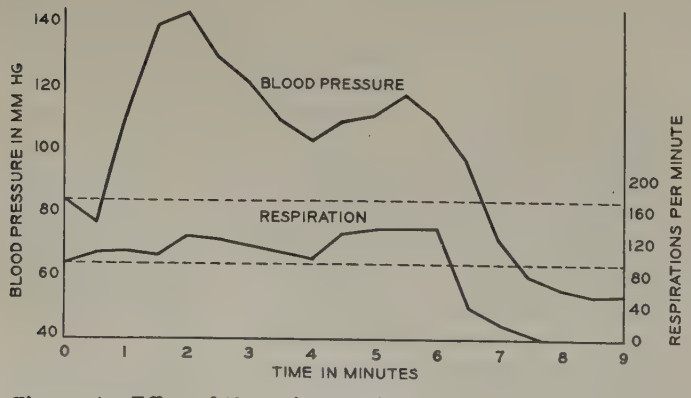

Figure 1. Effect of 10-centimeter electromagnetic waves at 2,000 watts output upon blood pressure and respiration in the rabbit

Table I. Lethal Effects of Ultrahigh-Frequency Radiations

Animal	Wavelength in Centimeters	Watts	Duration of Exposure	Latency for Lethal Effect
Rabbit	10	3,000	75 sec.	immediate
Rabbit	10	3,000	30 sec.	2 minutes
Rabbit	10	3,000	15 sec.	30 minutes
Rabbit	10	4,000	10 sec.	80 minutes
Rat	10	3,000	22 sec.	immediate
Rat	10	3,000	11 sec.	12 hours
Rat	10	3,000	17 sec.	6 minutes
Rat	10	4,000	10 sec.	immediate
Hamster	10	4,000	10 sec.	immediate
Hamster	10	4,000	6 sec.	50 seconds
Hamster	12¼	100	2 min.	immediate
Rat	12¼	100	6 min.	1 minute
Rat	12¼	100	4.5 min.	immediate
Rat	12¼	100	4 min.	97 minutes

Table II. Changes in Temperature in Various Areas of the Anesthetized Rabbit During Irradiation With 12-Centimeter Electromagnetic Waves

Region	Time in Minutes From Onset of Irradiation: 1	2	3	10	20	30
	Temperature Change in Degrees Centigrade					
Ileum	+4.2		+14.4	+29.5	+38.5	+42.9
Stomach	+1.8	+3.4	+5.4		+19.2	+23.1
Gall bladder	+0.1	+0.3	+1.8	+4.0		+6.3
Urinary bladder	+1.3	+2.1	+3.0	+5.6		+9.7
Rectal	+0.1		−0.1	+0.2		+0.8
Oral	−0.2		−0.2	−0.5	−0.9	−1.2

In experiments in which limited areas of the body such as the abdomen were irradiated with relatively lower energy outputs of electromagnetic waves, it was found that the temperatures of the visceral organs were markedly elevated whereas the oral and rectal temperatures remained within normal limits. This marked increase in temperature was found to be particularly true for the contents of hollow viscera such as the stomach, intestine, gall bladder, and urinary bladder where relatively avascular conditions prevail (Table II). These findings point to the limitations of oral and rectal temperatures as indicators of temperature changes elsewhere in the body. Severe and injurious temperature increases may occur in certain local areas during irradiation and yet be accompanied by only a slight increase, or even a fall, in rectal and oral temperatures. Data are summarized in Figure 2 for the results of experiments in which effects of irradiation of certain local areas upon the temperature of the brain were investigated. In some experiments the abdomen was irradiated for 20 minutes with 10-centimeter waves at a power output of 100 watts. In other experiments the head area only was irradiated. Results of the studies indicate that an excessive

rise in the brain temperature is not the primary cause of death when only the abdomen is irradiated but may well be the primary cause of death when the radiations are applied directly to the area of the head.

It would appear as if the lethal effects of radiations applied to limited areas of the body are somewhat different from those in which the whole animal is exposed. When only the abdomen is irradiated, death appears to be preceded by a syndrome which resembles that found in burn shock and in traumatic shock. It is suggested that treatment for the shocklike condition associated with the overexposure of local areas of the body to high-frequency electromagnetic waves would be similar to that employed in the treatment of traumatic and burn shock which includes the infusion of either plasma or whole blood.

WAVELENGTH OF RADIATION IMPORTANT

In a previous report[1] it was pointed out that the effect of electromagnetic waves upon the temperature of living and of dead tissues depends upon wavelength. In comparative studies made with 1,600-, 75-, 12-, 8-, and 3-centimeter radiations it was found that the shorter electromagnetic waves were relatively more effective for increasing the temperature in superficial tissue than in deeper tissues and that the longer wavelengths were more effective for heating of deep tissues than for superficial tissues.

Attention has been called previously to the unusual susceptibility of testicular tissue to elevated temperatures. A study has been made[2] concerning the effects of 12-centimeter waves upon the testes of adult rats. It was found that a single 10-minute exposure to microwaves caused testicular degeneration at a temperature of only 35 degrees centigrade measured in the central areas of the gland.

Another hazard that may result from exposure to high-frequency electromagnetic waves is that of damage to the eye in the nature of cataract formation. A direct single exposure of rabbit eyes to 12-centimeter microwaves at a 5-centimeter distance for 15 minutes with 100 watts of power output resulted in the formation of cataractlike lesions in the lens of the eyes after a delay of 3 to 9 days[3]. A series of repeated exposures to a smaller energy output of this frequency of electromagnetic waves resulted in the formation of cataracts after delays ranging from 2 to 42 days. A direct single exposure of rabbit eyes to 3-centimeter pulsed microwaves (radar type) at a 5-centimeter distance and 67-watt average output, resulted in opacities in the eye after delays ranging from 2 to 60 days.[4] Opacities were found to occur inside the cornea and on the anterior segment of the lens. When induced temperature gradients in excised eyes of beef were plotted it was found that the point of maximum temperature agreed well with the site of the damage which was found in the eyes of living animals subjected to irradiation.

Finally, attention is called to a hazard to which certain people may be vulnerable. Reference is made to the effects of exposing subjects with metal implants to radiations. It was found in a study carried out on rabbits that irradiation with 12-centimeter waves caused a greater temperature increase in tissue containing metal implants than in control tissue.[5] It is believed that the radiations

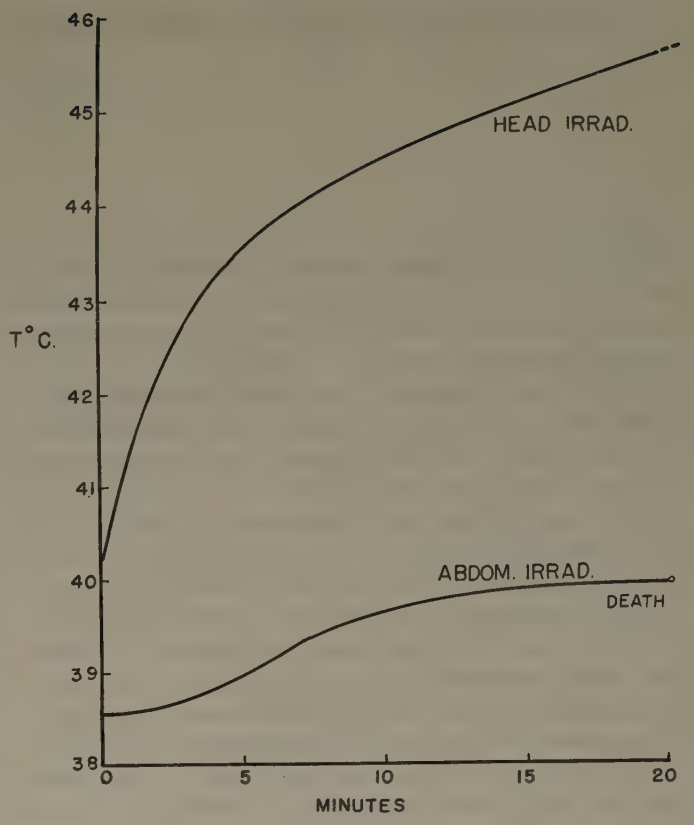

Figure 2. Temperature changes in the cerebrum of the rabbit produced by microwave irradiation of head and abdominal regions

penetrate the tissue and upon reaching the metal plate are reflected back, setting up standing waves in the tissue between the metal implant and the external surface. These energies are added to those of the original radiations, so that a much greater temperature increase occurs in these areas. The effects of metal implants depend upon the depth of implant and upon the relationship of the size of the foreign body to the wavelength in tissue.

CONCLUSIONS

It is desirable to shield the body from exposure to high-energy outputs of electromagnetic waves and to protect certain vulnerable structures during periods of treatment with microwaves. Tests in the authors' laboratory have shown that such structures as the eye and testes can be protected from even high-energy fields by covering the surfaces of the structures with close-fitting copper or bronze screen wire.

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Dial-Reading Translator for Digital Machine Inputs

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THE OPERATING COST of large transonic wind tunnels, such as the Southern California Co-operative Wind Tunnel (CWT), is so high that it is important that the data be recorded as quickly and efficiently as possible without sacrificing reliability. The time-consuming task of permanently recording the many measurements required during the testing of modern airplanes has led to the recent development of several automatic recording devices which read the position of a force-measuring instrument, translate the reading into a whole number, and then print the number on a data sheet. None of these devices seemed to be suited particularly to the reading of the potentiometers which are currently used at the CWT for indicating forces by means of resistance strain gauges mounted on small balances within the model.

Consequently, the following specifications were set up to meet the CWT needs: 1. the translator should transmit the reading of a self-balancing potentiometer to a standard punched card tabulating machine; 2. the translator should not restrain the movement of the potentiometer either during indexing between counts or while readings were frozen during the printing cycle; 3. the reliability must be as high as possible and the maintenance as low as possible.

One of the basic requirements for any device to transform a dial reading into circuits suitable for punched card machine use is that the dial position must be expressed in whole numbers or digitized. The method chosen for digitizing units is shown schematically in Figure 1. In Figure 1, relay coils Numbers 9 and 0 are energized by the rotating brush which happens to be at an intermediate position. The relay contact circuit selects the nine lamp until the rotating contact moves completely off of positio Number 9, moving toward position Number 0, when relay Number 9 is de-energized and transfers the count by mea of its normally closed contact to output lamp Number 0.

Indexing in the tens system is accomplished by a simila method except that two rotating brushes are used and the units count is used to make the choice between the two tens brushes. In Figure 1, the units count of 9 is selecting the trailing contact and a tens count of 20 for a total count of 29. As soon as the nines relay is de-energized, the resultant count of zero will select the tens count for a total count of 30. This method accomplishes the same function as the intermittent motions devices in many mechanical counters and has the advantages that torque is independent of count, that speeds greater than the relay response speed do not cause damage or loss of count upon slowing down to the maximum digitizing speed, and that it counts down as easily as up. Because of the necessity of providing circuits for additional functions such as printing circuits, checks against certain types of errors, and negative numbers, the actual device is more involved than is shown by Figures 1 or 2.

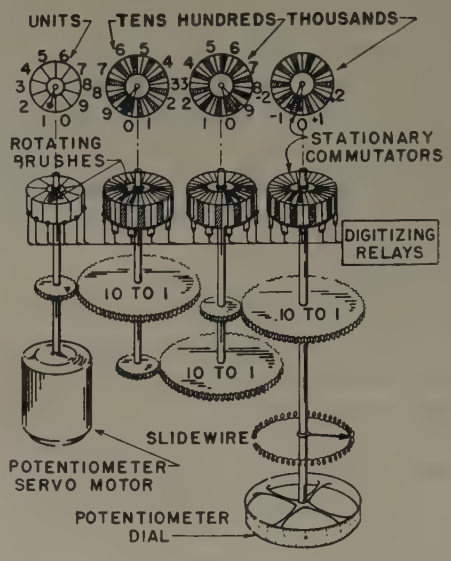

Figure 2. General mechanical arrangement of dial-reading translator

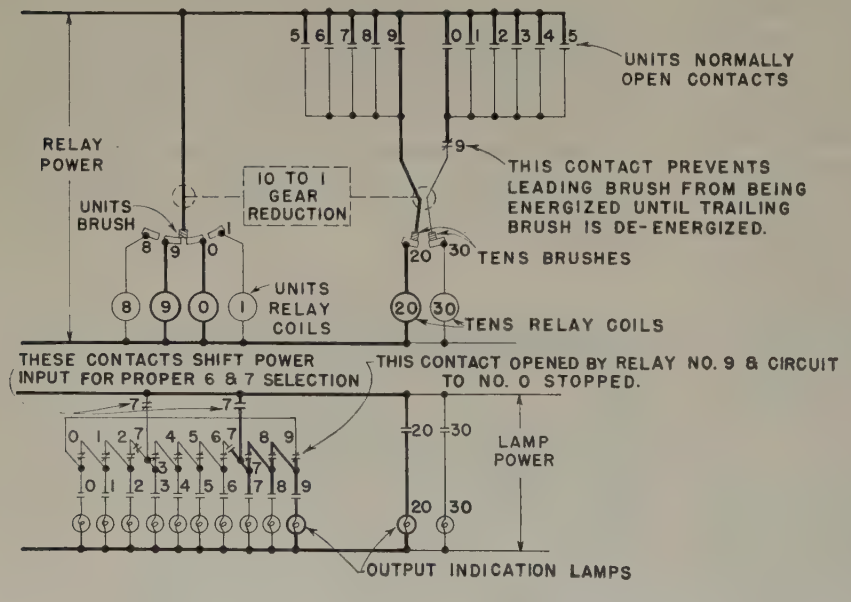

Figure 1. Circuit for digitizing units and controlling tens transfer shown at count of 29

Digest of paper **52-118**, "A Dial-Reading Translator for Digital Machine Inputs," recommended by the AIEE Committees on Air Transportation and Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Binghamton, N. Y., April 30–May 2, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Progress in Design of Diesel-Electric Switchers

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THE MODERN INDUSTRIAL switching locomotive had its beginning some 60 years ago. At first it was just electric—the diesel-electric offshoot not appearing until 1925. Fundamentally it is still electric, only its source of power is different.

Early diesel-electric switchers with their high cost, low power, and heavy weight were excluded from the industrial switching field with its low load factor. In the late 1930's all this was changed by the development of high-speed automotive diesels and electric drives to suit them. The application of this equipment to the diesel-electric locomotive marked the dawn of the day of the industrial switcher. Significant progress has been made since in the elements responsible for the customer acceptance and satisfaction that have characterized these locomotives from the first.

Steady improvements have been made which serve to increase the over-all locomotive efficiency, thereby bettering performance and reducing operating cost. One such instance is the development of the double-reduction geared traction motor. This has halved the motor losses at high tractive efforts, an important item in switching service. Utilization of only two types of motors to cover the entire line of locomotives, from 25 to 95 tons, permits a high degree of standardization and interchangeability of parts. The fact that these motors are self-ventilated further reduces the power losses and simplifies the locomotive design.

Experience with the first high-speed traction-type generators indicated that certain minor modifications were desirable. Most significant of these was the addition of a cranking winding for starting the diesel. Today, as a result of careful planning and design, three types of generators cover the entire line of locomotives. They all have simple shunt-type exciting field windings, and, except for the 95-ton locomotive, essentially are self-excited. The latter uses a belt-driven split-pole exciter.

The control for these locomotives consistently has been kept to a minimum number of functions and devices. Originally it provided only for no power and full power, but this proved unsatisfactory. By a simple improvement, battery excitation has been provided for the generator when only partial power operation is desired. By thus loading the engine at speeds only slightly above idling, slow movements of the locomotive are accomplished easily. As the throttle handle is advanced and the generator speeds up, the self-excitation increases and the battery excitation is removed in successive steps. No simpler control for a diesel-electric locomotive power plant ever has been devised, yet it enables utilization of practically full engine horsepower over the entire locomotive speed range.

The mechanical as well as the electrical aspect of the engine control has been improved. The engine governor always has operated only at idling and top speeds, and throughout its working range the engine is controlled by giving it more or less fuel manually. Refinements and simplifications of the throttle control linkage have overcome early deficiencies. The modern locomotive is easy to control and responds to the slightest wish of the operator.

Successive steps have been taken in the improvement and simplification of the air-brake system. Truck design and spring systems have been modified to give better riding qualities.

These and other improvements have resulted in locomotives with an average availability between 90 and 95 per cent. This is an important consideration for the average industrial user with only a few locomotives.

All this progress has done much to increase the life of the various locomotive components. Repair and replacement have been simplified greatly by improved design and better location of parts. The locomotive structure, and practically all equipment, are designed especially to resist shocks and other severe conditions found in switching service. Wherever possible, equipment is provided with antifriction bearings which will not require any attention between normal overhaul periods. Many of the standard components of these locomotives may be handled on the unit exchange plan. This gives the owner a repair and overhaul service without the burden of a heavy investment in tools and facilities on his part.

These locomotives were designed as a unified line, and duplication of parts and equipment throughout the range of sizes was carried out to the fullest degree. Common parts were standardized so that the benefits of repetitive manufacture could be realized. Where quantity justified special tools and processes were devised. Parts were laid out so as to reduce waste, and the use of subassemblies was introduced in the manufacturing process.

The design principles followed in this line have given the locomotives a similarity of appearance. Improved manufacturing processes have lent themselves to a certain amount of streamlining. This, coupled with the wide range of colors available in modern synthetic lacquers and paints, has given a definite eye-appeal to the modern industrial switcher.

Here is a picture of progress that has resulted in a complete line of locomotives of stabilized design that adequately covers a large segment of the industrial switching and haulage field. A purchaser is able to select the type and size that most accurately and economically meets his needs, and it will be a modern, efficient, standardized unit backed by years of design experience and manufacturing know-how.

Digest of paper **52-169**, "Fifteen Years' Progress in the Design of Diesel-Electric Switchers," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Nation-wide Telephone Numbering Plan

W. H. NUNN

At the present time a great variation in the types of telephone numbers exists. This is because of the number of telephones in communities of different sizes. With the advent of local dialing and now nation-wide dialing, a uniform numbering system has become necessary.

IN TELEPHONE language a numbering plan is exactly what the name implies: a plan or system of giving each telephone in a city, a town, or any geographical area an identity or designation which is different from that given every other telephone in this same area. This designation is the telephone number; it appears in the directory and in most cities on the telephone instrument itself. It is the address of the telephone in the telephone network. Just as it is essential for efficient postal and delivery service to have streets and house numbers clearly marked, it is important for good telephone service that the telephone numbering plan be such that it will be used with convenience and accuracy by the telephone customer.

A telephone number is comprised of two elements, a designation for the central office to which the telephone is connected and a number within the central office which identifies one particular telephone from all others served by that office. If there is only one central office in the city or town, the office designation is frequently omitted. A dial office is designed to serve up to 10,000 numbers with a limitation of four digits. Typical numbers are therefore MAin 2-1234, ADams 2345, 5-6789, and 3456, the office designations being MAin 2, ADams, and 5 with the last four digits in all cases representing the number within the central office.

There is a wide variation in the types of numbering arrangements in use today in the Bell System. This diversity arises from the fact that telephone communities vary greatly with respect to the number of telephones served, ranging all the way from New York City with its more than 3,000,000 telephones and 300 central offices to small villages and rural communities with perhaps a few score or a few hundred telephones.

In the 1920's, when the Bell System embarked upon its program of converting local offices to dial operation, each exchange or city was in general an entity unto itself. Customers dialed local calls within their own city but all calls involving a toll or multiunit charge required handling by operators for timing and ticketing. There was no advantage, therefore, in making a numbering plan for a given city more comprehensive than required to serve the telephones and central offices in that city with a suitable allowance for the expected growth. Thus a multitude of local dial communities, large and small, were formed within which customers could dial their own calls and connections between these telephone communities were established by operators.

Over the years these basic numbering plans which were originally established for local dialing have proved inadequate in many of the cities to furnish as many office codes as later events have shown are required. This is due to a variety of causes. The station growth in many places has outstripped all expectations and the number of central offices required to serve this unprecedented demand for service consume many more office codes than the original plans provided.

In many places local service areas were changed so that customers could call into contiguous exchanges at local rates. To enable customers to dial into these near-by places the original numbering plans required expansion to include this increased number of offices. In addition, with the advance in the telephone art many cities introduced equipment for automatic charging on multiunit and short-haul toll calls so that customers could dial such calls directly instead of placing them with an operator for completion. In order to enable customers to dial these calls, it was necessary to expand the original city numbering plans to encompass wider and wider geographical areas.

In expanding the various types of numbering plans to serve a larger number of central offices than were originally anticipated, various expedients were employed. In the largest cities having 3-letter office codes a numeral was substituted for the third letter thus very materially increasing the code capacity from about 325 to about 500 and making it possible to form a number of codes using the same office name. The name CANal, for example, instead of serving but one office may serve a number of offices: CAnal 2, CAnal 3, CAnal 4, and so forth. In the medium-sized cities having 2-letter codes, expansion meant adding a digit to the code to all or in some cases to only a part of the offices in the city.

The 5-digit places were usually expanded by adding a digit to some of the numbers so that some of the telephones had five digits and others six digits in their numbers.

As a result of choosing originally a numbering plan which at the time seemed adequate and most suitable for the city involved and in many cases being forced to expand to meet changing needs, we now have in the Bell System

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Table I. Telephone Numbering Plans Used in Bell System

Place	Directory Listing	Customer Dials	Ordinarily Referred to as
Philadelphia, Pa.	LOcust 4-5678	LO 4-5678	Two-five
Los Angeles, Calif.	PArkway 2345 and REpublic 2-3456	PA 2345 and RE 2-3456	Combined two-four and two-five
Indianapolis, Ind.	MArket 6789	MA 6789	Two-four
El Paso, Tex.	PRospect 2-3456 and 5-5678	PR 2-3456 and 5-5678	Combined two-five and five digit
San Diego, Calif.	Franklin 9-2345 Franklin 6789	F 9-2345 F 6789	One letter, four and five digit
Des Moines, Iowa	4-1234 and 62-2345	4-1234 and 62-2345	Combined five and six digit
Binghamton, N. Y.	2-5678	2-5678	Five digit
Manchester, Conn.	5678 and 2-2345	5678 and 2-2345	Combined four and five digit
Winchester, Va.	3456	3456	Four digit
Ayer, Mass.	629 and 2345	629 and 2345	Combined three and four digit
Jamesport, N. Y.	325	325	Three digit

a considerable variety of different numbering plans. These are illustrated in Table I. The numbering plans illustrated are all adequate to serve the present local dialing needs for the cities in which they appear.

HANDLING TOLL CALLS

Having reviewed the numbering plan situation as it exists today in the various cities and towns, let us turn to the problem of handling toll calls. Under ring-down operation there is an operator at the outward toll center where the call originates and another operator at the terminating or inward toll center. On built-up toll connections there are additional operators at each intermediate toll switching point. The inward toll operators, who are familiar with the numbering plans in the offices served by their particular toll center, can be relied upon to connect to the desired station even though there is uncertainty on the part of the calling customer or the outward toll operator regarding the precise pronunciation or spelling of the name of the called office or the particular form of numbering system used at the called city.

Under operator toll dialing the inward operator is replaced by dial-switching equipment under the control of the outward operator; hence the outward operator has no one to rely upon but herself in completing a toll connection to a distant city. With the present method, the operator dials a code for each circuit group in the connection followed by the number of the called party which may consist of any number of digits from three to seven. The operator must refer to her position bulletin or to a routing operator for the correct circuit group codes unless she happens to remember them. Where the office to be reached has central office names, the operator must rely on routing information to determine how many letters of the name are to be dialed. The great variation in the number of digits to be dialed on different calls is a source of some difficulty and confusion to the operators.

The present system of operator toll dialing by which operators use codes depending upon the routes to reach a desired destination, is a great improvement over the old manual handling methods. However, with the introduction of more modern toll-switching facilities and the nation-wide extension of toll dialing, it was realized that an improvement in the methods for dialing toll calls to distant cities was essential in order to realize the maximum speed and accuracy inherent in toll dialing.

These handicaps in the present toll-dialing methods are to be overcome by establishing a nation-wide numbering plan covering the United States and Canada by which each of the more than 20,000 central offices in the two countries is to be given a distinctive designation which identifies that particular office and that office only. This designation is to consist of two elements: a regional or area code and a central office code. Any outward toll operator, wherever located, will use that same designation in reaching that office through the dial toll-switching network.

In a sense, all of the thousands of offices involved are to be treated as though they were contained in one huge multioffice city. Toll operators will use the area code and the office code in reaching an office situated outside her own numbering plan area, while on calls to points within her own numbering plan area she will dial only the number as listed for toll in the directory. In principle the method employed is to divide the two countries geographically into numbering plan areas and to give each of these areas a distinctive code. These are shown on the map of Figure 1. Within each of these numbering plan areas each office will have a code unlike that of any other office in the same numbering plan area and also unlike any area code. Hence for toll-dialing purposes each office will have an area code and central office code forming a combination unlike any other central office in the two countries.

In this geographical division into numbering plan areas, border lines between states and between Canadian provinces generally have been used as numbering area boundaries. Since about 500 central offices are the maximum number which can be served in a numbering plan area, it is necessary to divide the larger and more populous states and provinces into two or more areas making, of course, due allowance for growth. New York State with the largest number of central offices is divided into six numbering plan areas; Pennsylvania, Illinois, Texas, and California have four areas each. Other divided states have three or two areas, depending upon the number of offices to be served. Approximately 90 areas are being provided, with 14 states and two provinces served by two or more numbering plan areas, the remaining states and provinces by one area each.

In fixing the intrastate numbering plan area boundaries of subdivided states, among other considerations effort was made to avoid cutting across heavy toll traffic routes in order to have as much of the toll traffic as possible terminating in the area in which it originated. The advantage of arranging the numbering plan areas in this manner is readily apparent since on this traffic which does not pass an area boundary the area code is not required.

COMPOSITION OF AREA CODES

Let us now consider the composition of the area codes. As indicated previously they must be of a type which will enable the switching equipment to distinguish them from the codes of central offices.

On the telephone dial plate, letters are assigned only to

Figure 1. The telephone numbering plan showing areas of the United States and Canada with their codes. Each state is comprised of one or more numbered areas. Note that the second code digit of states with one area is 0 and those states having more than one area have a second code digit of 1. This is to enable toll operators to differentiate between the two classifications of areas

the dial positions 2 to 9 inclusive (on some dial plates a Z appears on the 0 position but the Z is never used in a central office code), hence any office code will always avoid a 1 or a 0 in the first two places. The digits 1 and 0 can be used therefore in area codes to distinguish these from office codes. It is not practical to use them as initial digits of area codes since customers dial 0 to reach operators and the local dial equipment is arranged to ignore an initial 1 for technical reasons. A 1 or 0 in the second place, however, can be employed in an area code without conflicting with any central office codes or interfering with any existing practices. Accordingly, the area codes will consist of three digits with either a 1 or a 0 as the middle digit, 516, 201, and so forth. A few codes of this type are now in use, leaving a practical total of 152 of these area codes available as compared to approximately 90 assigned to our present numbering plan areas. This will provide a comfortable spare for additional future numbering plan areas or possibly for reaching overseas points which may be incorporated later into the toll dialing network.

As shown in Figure 1, states and provinces such as Montana or Alberta which are contained in a single numbering plan area will have area codes with a 0 as the middle digit to distinguish them from areas in divided states such as Texas where the middle digit will be a 1. This is to enable toll operators to differentiate between the two classifications of areas. On calls to single-area states the operators always will know that every call to the state in question uses the 1-area code, whereas on calls to subdivided states additional information will be required to determine which of the several area codes should be employed to reach the particular destination. It is proposed to show on the operator position bulletin the codes of all single-area states and the codes of all frequently called cities in multiarea states. The area codes of the less frequently called places in the multiarea will be obtained from a routing operator.

Within each numbering plan area, each of the 500 or fewer offices is to be given a 3-digit office code which will be different from that of any other office code in that same area. Ultimately, each central office will be given a 2-5 type of number consisting of an office name and five numerical digits, such as LOcust 4-5678, illustrated for Philadelphia. In the larger cities customers will dial seven digits, LO 4-5678, on local calls to numbers in the same exchange. In many of the smaller places the customers on local calls will dial only the numerical digits, the office name being employed for toll dialing purposes only.

Considering the thousands of central offices which now have numbers other than the 2-5 type and the fact that to change existing numbering systems is a difficult and often costly procedure, it will be a number of years before this ultimate objective is realized. As a practical measure, therefore, it will be necessary during this interim period, before the central office names with the 2-5 type of number are established everywhere, to employ for operator toll dialing office codes which in many cases may not be derived from the customers' telephone numbers.

In dialing to a combined 2-4 and 2-5 city, for example Los Angeles, the 3-digit office code for the Parkway office, which has six digits in the local number, will be PAR; whereas to reach the Republic 2 office having seven digits in the local number, the office code will be RE2. To call a telephone in Winchester, Va., with only four digits in the local number, the operator will use a code consisting of numerical digits only, such as 294, which, of course, must be different from every other office code in this numbering plan area. To secure the particular office code to be used in reaching an office where the called number does not furnish complete information, the toll operator must refer to a position bulletin or the route operator. This reference work, of course, takes time and therefore imposes a delay in completing the call.

In addition to giving a distinctive 3-digit code to each office within each numbering plan area, each toll center also will be given a 3-digit code to enable outward operators to reach inward information, and delayed-call operators at toll centers in distant cities. Calls to these operators will be routed in the same manner as calls to customers except that the operator codes will be used instead of a station number and a toll-center code in place of a central-office code.

CENTRAL OFFICE NAMES

The central office names now in use in the various cities in the Bell System were chosen, generally speaking, on the basis of their suitability for customer dialing within the city itself. Many of these names are unfamiliar words to operators and customers in distant cities and the use of these names contributes materially to the operator dialing errors. This situation is gradually being corrected by using for new offices, names from a Bell System approved list and replacing existing names which experience has shown to be particularly troublesome by names from this list.

While numbering plans are important in operator toll dialing, they play an even more essential part in the dialing of toll calls by customers. Operators can be trained to adapt their dialing procedures to the type of local numbering system encountered in the called city even though more time is consumed and more errors result than would be the case if all telephone numbers were of a uniform type. Customers, however, could not be expected to follow any plan which requires a variety of different procedures to be used in reaching different cities. Only a numbering system which is readily understandable and which customers find convenient to use and one which they can use with a very high degree of accuracy, will suffice. The need for accuracy is readily apparent since with the customer's telephone being given access to the intertoll network without the intervention of an operator, a call which is misdialed can be routed to a telephone thousands of miles from the desired destination.

At present, customer dialing of toll and multiunit calls is confined, for the most part, to situations where the call can be completed by the use of the number as listed in the directory without any additional digits being dialed. In a few cases, as from Camden, N. J., to Philadelphia, and certain offices in Northern New Jersey to New York City, the code 11 is prefixed to the listed number. In the case

of the current trial of customer toll dialing at Englewood, N. J., the customers are using area codes such as 415 for Oakland, Calif., 312 for Chicago, and so forth, dialing only into those cities which now have the 2-5 type of numbering.

THE 2-5 NUMBERING SYSTEM

From the Englewood experience it can be confidently predicted that this form of dialing, that is, an area code followed by a telephone number consisting of a uniform number of digits, is one that customers will use with a reasonable degree of convenience and accuracy. The problem therefore to meet the requirements for nation-wide customer toll dialing, is to establish universally for all central offices regardless of size and location a uniform pattern of numbering for toll purposes. The only form of number completely filling the needs is the 2-5 system, which is that used in the largest cities today.

Accordingly, in order to implement the program for customer dialing of toll calls on a nation-wide basis, it will be necessary to place all telephone numbers on a 2-5 basis with the code of each office different from that of every other office in the same numbering plan area. Thus, each of the 50,000,000 telephones in the United States and Canada will have, for toll dialing purposes, a distinct identity consisting of ten digits: a 3-digit area code, an office code of two letters of an office name and a numeral, and four digits of the station number within the office. Typical numbers for toll dialing therefore would be 601-CA3-4567 or 317-MA7-6789. As with operator toll dialing, on a toll call which terminates in the same numbering plan area in which it originates, the area code will be omitted and the office code and station number, a total of seven digits, will be used.

With this universal 2-5 type of number, local calls in and about the larger and medium-sized exchanges will be completed by dialing the entire 7-digit number. For many of the smaller places in the more isolated sections, 5-digit or 4-digit dialing will be employed frequently where this number of digits will be adequate for all of the telephones in the customers' local dialing area. For these offices with 5- or 4-digit local dialing and for offices in the larger places served by certain types of dial equipment, as they are arranged today, it will be necessary to prefix the dialing of toll calls by a transfer or directing code to permit the customer getting from the local office into the toll network.

CONCLUSION

Independent of the advantages of a universal 2-5 numbering plan for nation-wide operator and customer toll dialing, the Bell System has made considerable progress in this direction over the past several years. New York and Northern New Jersey adopted 2-5 numbering in 1930 in order to take advantage of the flexibility of office code assignments and the large code capacity which this type of local numbering provides. Since World War II many cities and their environs such as Chicago, Boston, Philadelphia, San Francisco, Oakland, Pittsburgh, Milwaukee, Providence, and a number of smaller cities have followed suit. Presently about 12,000,000 telephones are in areas which have 2-5 numbering exclusively in addition to perhaps 2,000,000 telephones with 2-5 numbers in mixed 2-4 and 2-5 areas. Another 5,000,000 telephones are already planned for conversion to 2-5 numbers within the next several years.

The entire program will take many years to realize but it is one which must be accomplished in order to achieve the best results in operator toll dialing and make it possible for a customer at any telephone in the United States and Canada to reach a telephone anywhere in the two countries by dialing without the assistance of an operator.

Delivery of Stator Poses Transportation Problems

Two years of transportation planning were climaxed recently with delivery of a giant General Electric 401,000-pound stator for one of the world's largest generators in Consolidated Edison's East River Station at New York, N. Y. Taxing transportation facilities enroute from the turbine manufacturing center at Schenectady, N. Y., the stator moved by rail, water, and heavily reinforced trailer to the powerhouse at 14th Street and East River Drive.

Two railroads, a specially built flat car, one of the world's largest floating derricks, a lighter, two tugboats, and a firm of heavy hauling specialists were needed to move the giant 30-foot-long component of a 175,000-kw generator.

During the past 2 years, engineers, shipping and and transportation experts had carefully measured every step of the way. The first part of the journey from Schenectady to Jefferson Junction, N. Y., was via Delaware and Hudson Railroad. From Jefferson Junction, the Erie Railroad ran a special train to Jersey City (N. J.) Marine Dock, Pier #1. From the track at the edge of Marine Dock, the biggest commercial floating derrick in the United States hoisted the load from flat car to lighter. The lighter was towed by tug around the lower end of Manhattan to the foot of 34th Street on the East River, where the stator was lifted to a reinforced tractor-trailer. The unit's bulk made necessary a special route through the city. So small were clearances on some turns that lines were painted on the street for the guidance of those handling the job. Movement was made through New York streets in the early hours of the morning. Careful planning and expert handling resulted in delivery of the stator without incident, despite clearances which in some cases were less than one inch and loads which came within a few hundred pounds of rated capacity.

Automatic Toll Switching Systems

F. F. SHIPLEY
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The new system was designed to implement the nation-wide switching plan which integrates the telephone switching network of the entire nation into a single unit. Requiring a high order of mechanical intelligence, this system is one of the most comprehensive ever devised.

THE MAJOR switching centers required for the nation-wide automatic switching plan are called Control Switching Points (CSP's) and are supplied with switching equipment endowed with great versatility and a high order of mechanical intelligence. Mr. Pilliod's article[1] explains how for purposes of circuit layout and routing, they are assigned different rankings as follows, starting with the lowest: Primary Outlets (PO's), Sectional Centers (SC's), Regional Centers (RC's), and one National Center (NC). Substantially the same equipment is to be provided for all of these centers so that they all will have inherently the same capabilities; they will, however, differ greatly in size. In the United States and Canada, as now envisaged, there will be somewhat under 100 of these CSP's.

The system which the Bell Telephone Laboratories developed for use at CSP's and which embodies all of the features required at those important switching points is based on the Toll Crossbar System[2] now in service and has been constructed by the addition of the necessary CSP features to the basic structure of that system.

CSP SWITCHING SYSTEM FUNCTIONS

THE SYSTEM is designed to be suitable for location in either a step-by-step or a panel-crossbar local area. In addition to the functions required for operation as a CSP, it must perform, of course, the normal toll switching functions required of any system for switching the toll traffic characteristic of the locality it serves. These may be stated very briefly.

Ordinary Toll Switching Functions.

1. It accepts calls either directly from operators or from senders in distant offices. In the interest of economy, it accommodates itself to the signaling language the operator's position or sender is equipped to deliver. Calls from operators may be either in the dial pulse (DP) or multi-frequency[3] (MF) form. Calls from senders will be in the MF form.

DP pulsing is the decimal type delivered directly by the dial and is at the rate of about one digit per second. MF pulsing represents a particular digit by a combination of two out of five frequencies in the voice range; it uses one of these frequencies in combination with a sixth frequency to produce a signal indicating the beginning of pulsing, and a different one of the five in combination with the sixth for an end of pulsing signal. It is transmitted from senders at the rate of about seven digits per second. Operators usually key at the rate of up to two per second.

2. The toll switching system completes calls to various types of mechanical toll and local offices and to operators, using the form of signaling dictated by economy for each call.

3. It must transmit signals in one direction for initiating, holding, and releasing the connection, and in the opposite direction to indicate to the originating end when the called subscriber answers and hangs up. These signals must be in a form suitable for propagation over the medium which carries them.

4. It must exercise control over the amount of amplification of voice currents introduced at the switching point so that a proper grade of transmission will be furnished.

All of these functions are performed by toll crossbar systems already in service. The features that distinguish the new system are those peculiarly characteristic of CSP operation.

CSP Functions. The following features which will be built into the equipment at control switching points are commonly referred to as CSP features:

1. Storing and sending forward digits as needed.
2. Automatic alternate routing.
3. Code conversion.
4. Six-digit translation.

The first of these features is basically essential for implementation of the plan. The second produces faster service and important economies in outside plant. It also provides protection against complete interruption of service in case of failure of all circuits on particular routes. This aspect of the feature is so important that automatic alternate routing also may be considered essential. The other two features are provided for reasons of economy, and produce economies of such magnitude that they are very much worth while.

1. *Storing and Sending Forward Digits as Needed.* The necessity of providing this feature in CSP switching systems arises from the nature of the numbering and switching

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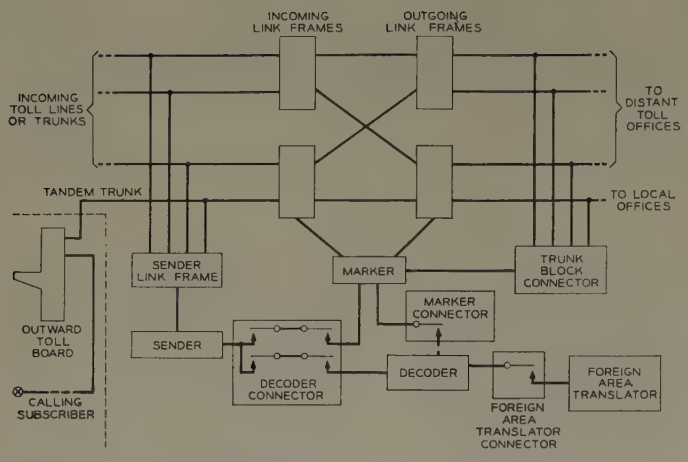

Figure 1. Schematic diagram of crossbar switching system for control switching points

plans. The numbering plan[4] is constructed with the objective of using a minimum number of digits to give each telephone user in the country a distinctive number.

Numbers delivered to the CSP equipment are in the form ABX-XXXX if the called place is in the same numbering area as the CSP. AB represents the first two letters of any office name and X represents any numeral. If the called place is in another numbering area this set of digits will be preceded by X0X or X1X. X0X or X1X is the area code, ABX the local office code, and these are the digits used for routing purposes. Regardless of the number of switches required to complete the call, these two sets of code digits are all that will be supplied. They are universal codes in that they identify specific destinations, any place in the United States or Canada, and for a particular destination the same set of digits will be used wherever the call may originate. All CSP's therefore, must be able to advance a call toward the same place when the same set of digits is received. To make use of destination codes possible, each CSP must store the digits as received and pass along to the next point whatever digits may be required there for advancing the call.

2. *Automatic Alternate Routing.* The system is arranged to offer the maximum number of alternate routes possible under the switching plan. As explained by Mr. Pilliod,[1] a maximum of five alternates actually will be used. This number is possible, of course, only at PO's since higher ranking CSP's have fewer CSP's above them in the final chain.

3. *Code Conversion.* This refers to the ability to substitute one, two, or three arbitrary digits for the area code, the office code, or both. It is economically important to be able to do this because it makes it possible to work with the step-by-step equipment extensively used in local offices and in toll offices in Ordinary Toll Centers (TC's) or Tandem Outlets (TO's) without the changes in local numbering plans or rearrangements, and in some cases extra selectors, required for the step-by-step TC's or TO's to use ABX codes for routing purposes.

4. *Six-Digit Translation.* When a CSP receives a 10-digit number it is sometimes sufficient to translate only the area code digits and sometimes necessary to translate both the area and office codes. If all points in the called area are reached by the same route out of the particular CSP concerned, the area code will suffice for selection of the route. If some points are reached by one route and others by one or more different routes, the office code must be translated also to determine which route should be selected.

BASIC ARRANGEMENT

In the CSP switching equipment, talking connections are established through crossbar switches.[5] Incoming and outgoing toll lines and toll connecting trunks are terminated on crossbar switch frames with linkage between them to provide full access. The switches are controlled by equipment common to the office, each item of which is held only long enough to perform its task in setting up the connection.

The major items of common control equipment are senders, markers, decoders, and translators. The basic functions of the senders are the same as in other common control systems, that is, registering incoming digits and sending them out as directed. A departure from prior practice is made in the design of the marker. In other crossbar systems the marker is the principal seat of the mechanical brains. It not only controls the actual establishment of the connection, but also does the translating to determine what connection should be established and what information should be passed to the sender for further disposition of the call. In this system the marker still controls the actual setting up of the connection, but it acts on instructions received from the decoder where the major portion of built-in intelligence resides.

The decoder accepts code digits from the sender, translates them, makes selection of alternate routes, and gives instructions to markers and senders to enable them to carry out their assignments. To do the translating job the decoder has one, and in some cases two, translators permanently associated with it and in addition has access to a common group of translators called foreign area translators which can be used by all decoders as required.

The relationship of the principal elements of the system to each other is depicted in the schematic diagram, Figure 1.

METHOD OF OPERATION

The manner in which the various elements of the CSP system and the CSP systems at various locations cooperate to implement the nation-wide switching plan may be understood best by following the progress of a call which demands the exercise of the characteristic CSP functions.

Assume an outward operator in Atlanta has received a station-to-station call for a subscriber in Monticello, Maine, whose number is ACademy 4-2345; that Monticello is a tributary of Houlton, a step-by-step TC; that Bangor is a step-by-step TO serving Houlton as its home TO, and that the circuit groups provided are as indicated in Figure 2. The dotted lines represent high-usage groups and the solid lines final groups.

The Atlanta operator plugs into a tandem trunk to the

toll crossbar system in Atlanta, thereby causing a sender to be attached to the trunk through the sender link frame. This causes a lamp signal to be displayed to the operator, indicating that she may key the number. She keys 207-AC4-2345 plus a start signal (signifying end of keying) into the sender and leaves the connection to handle other calls. She will give this call no further attention until the lamp associated with the cord circuit used in establishing it signifies either by flashing that the call was not completed due to a busy condition of the called line or to circuit congestion, or by going dark that the called subscriber has answered and she should start timing the call.

As soon as the area code, 207, is received by the sender it calls for a decoder and gives it the code. The decoder, by means of a self-contained translator, finds that the area code is sufficient for routing purposes, that the first choice route is by way of Boston, the second New York, and the final St. Louis. Without consulting other circuits it will know in which of these groups an idle circuit may be found. Let us assume that the circuits to Boston are all busy but there are one or more idle circuits in the New York group. The decoder calls for a marker and tells it which group of leads to test, and also causes the sender to be connected to the particular marker it has selected.

The marker, following instructions from the decoder, is connected to the appropriate trunk block connector. This is one of a group of common circuits giving access to "blocks" of trunks for allowing the marker to locate an idle trunk. The marker examines the test leads of the individual toll lines to New York and as soon as it has selected an idle circuit it so informs the decoder. The decoder then tells the sender to send all digits forward by MF and leaves the connection to accept another call. This information is relayed from the decoder to the sender by way of the marker. The work time of the decoder has been in the order of a half second.

The marker determines the identity of the frames on which the incoming and outgoing circuits are located, finds an idle path between the two circuits, and sets up the connection. After checking the path through the switches to be sure that there are no troubles, it notifies the sender that its task has been completed and then leaves the connection. Its work time also has been in the order of a half second.

In the meantime other digits have been coming in to the sender but it does not wait for all of them to arrive before advancing the call. When the marker selected the circuit to New York a signal was immediately sent forward to summon a sender in the New York switching system. The process of attaching the sender in New York was carried on concurrently with the establishment of the connection through the switches in Atlanta.

When the New York sender is attached, a signal is sent to the Atlanta sender to advise it that pulsing may proceed. It immediately sends the area code 207 to New York by MF pulsing and follows it with the remaining digits of the called number, AC4-2345, as they are received from the operator, ending with a start pulse, and then leaves the connection. All common control equipment in Atlanta is now free.

In New York, as soon as the Maine area code is received it is submitted to the decoder. Upon examination of the code the decoder finds that it is insufficient for routing purposes. New York has a direct circuit group to Portland over which traffic to some offices in Maine is routed, but other offices are reached through Bangor by way of Boston. In order to determine which route to take the decoder must know what office is desired. It, therefore, gives the sender a signal saying "come again when you have six digits" and leaves the connection. When the sixth digit arrives the sender again calls for a decoder and gives it the complete code 207-AC4.

The decoder again translates the area code, which now directs it to the foreign area translator which serves the Maine area, and submits the complete code to that translator. From the ensuing translation it learns that the route is by way of Boston and that all digits should be sent forward by MF. It then calls for a marker and releases the foreign area translator.

Subsequent operation is the same as previously described for Atlanta and the complete 10-digit number now arrives at Boston. At that point both codes are again translated since Boston also has a choice of routes to Maine, and the route to Bangor is selected. The translating equipment in Boston knows that Bangor is in the Maine area and that the area code, therefore, will not be needed. However, since Bangor is a TO having no senders, the Boston sender must pulse forward all of the digits needed to complete the

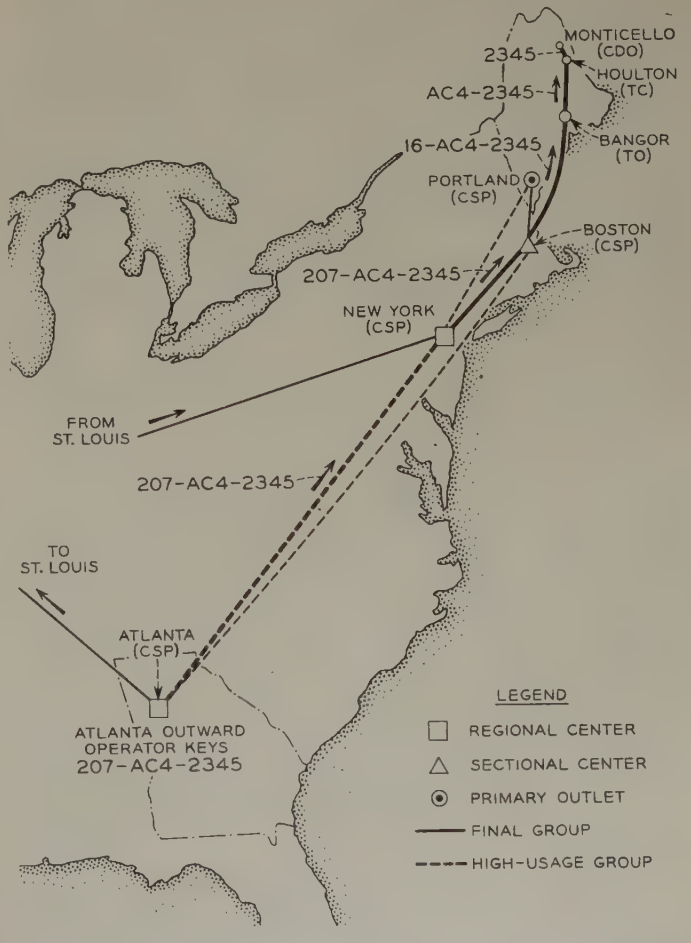

Figure 2. Route of call from Atlanta, Ga., to Monticello, Maine

call through switches in Bangor, Houlton, and Monticello. It is assumed that Houlton is arranged to route the call to Monticello on receipt of the digits AC4. Numerical digits 2345 will route the call through the Monticello switches to the called customer's line. These digits are all registered in the Boston sender, but the digits required to switch the call through Bangor are not and must be supplied. An arbitrary set of digits beginning with "1" can be used for this purpose since no office code begins with "1" and thus there will be no conflict.

The decoder in Boston, therefore, gives the sender the proper set of arbitrary digits, say 16, to be placed ahead of the office code AC4. The sender sends forward by the DP method 16-AC4-2345 driving switches in Bangor, Houlton, and Monticello to the called subscriber's line, and ringing starts automatically. The talking connection is now established and the common control equipment at all intermediate points is free.

When the called subscriber answers, the Atlanta operator's cord lamp is extinguished. When he hangs up, the lamp lights to denote end of conversation. The removal of the operator's cord automatically releases the entire connection, the release of each link causing the next in line to release.

In setting up this call all of the characteristic CSP features were employed, automatic alternate routing in Atlanta, 6-digit translation in New York and Boston, digit storing and variable spilling at all CSP's with substitution of arbitrary digits for the area code at Boston.

TRANSMISSION

All talking connections through the CSP system are made on a 4-wire basis, that is, separate pairs of conductors are provided for transmission in the two directions. This is done in order to simplify the problem of maintaining satisfactory balance so that the loss introduced by extra links in a connection can be held to a minimum value. The importance of this feature is emphasized by the fact that the switching plan permits as many as eight intertoll trunks to be connected in tandem for the completion of a call.

The advantages of 4-wire switching were fully explained in the paper[2] on the toll crossbar system now in service.

SIGNALING

In following the progress of the call from Atlanta to Monticello, Maine, it was observed that besides the transmission of information in the form of digits it was necessary to pass a number of control and supervisory signals over the toll lines. These included seizure and disconnect signals in the forward direction and switchhook supervisory signals and sender attached signals in the reverse direction. On some calls it is also necessary to send flashing signals to indicate busy lines or trunks and ringing signals in either direction when operators are called in at intermediate or terminating points to assist in establishing connections.

For the early toll dialing installations the signaling method most widely used was the composite method whereby signaling channels for the three circuits of a phantom group are derived from three of the conductors with the fourth being used for earth potential compensation. Direct current is used for signaling. This is a simple, reliable, and economical method of signaling and will continue to be used on circuits where it can be applied.

Where circuits are obtained from carrier systems, however, conductors are not available in sufficient numbers for signaling channels and other methods must be employed. Since carrier is used almost exclusively on the long haul circuits, it was necessary to provide a signaling system to accompany it before toll dialing could be expanded beyond networks of limited range. To meet this situation a system[6] using a frequency of 1,600 cycles was developed and has been in service since 1948. Signaling is done by application and removal of the 1,600-cycle signaling current. The system is used in the same manner as the composite signaling system, to carry dial pulses as well as supervisory signals when used on circuits that require it. The set of leads brought out of the signaling unit are identical in function to those brought out of the composite signaling unit so that toll-line relay circuits will operate in the same manner with either type of signaling.

Since 1,600 cycles is in the voice range, the signaling current can be carried over the same channel that carries the speech current, but the signaling circuits must be protected, of course, against false operation due to speech and precautions likewise must be taken to insure that the signaling tone does not interfere with speech. Protection against interference between signaling and speech is more difficult at 1,600 cycles than at higher frequencies because there is more energy in voice currents at the lower range. That value was chosen, nevertheless, so that it would be possible to operate over the narrow-band circuits that were established to relieve shortages occasioned by the war.

A new 2,600-cycle system to be used only on the broader band circuits has since been developed. It is simpler and more economical than the 1,600-cycle system. The older carrier systems, having been designed when practically all toll operation was by the ringdown method, made no provision for signaling since that was all done by short applications of 1,000 cycles when there was no speech on the line. Some of the new carrier systems for short-haul applications are designed to provide their own signaling channel for each voice channel.

PRINCIPAL ELEMENTS OF THE CSP SYSTEM

1. *Crossbar Switch Frames.* Crossbar switches are used for incoming and outgoing link frames on which the trunks (both toll lines and trunks to and from local offices and switchboards) are terminated, and for sender link frames used to give trunks access to senders. These frames are similar to those in the toll crossbar systems now in service. Since they have been described in a previous article,[1] they will be passed over with only a mention of their capacity.

Each incoming or outgoing link frame normally has terminals for 300 trunks. As many frames are provided as required for the size of the office. In the smaller offices one train of switches with complete interconnection of

incoming and outgoing frames is provided. In the larger offices two trains each with its own set of markers are provided. When this is done the incoming trunks are multiplied to both trains and an extra build-out bay is provided on the incoming frame to provide 400 terminals per frame. Since each train has a theoretical limit of 40 incoming and 40 outgoing frames, the maximum size of an office is theoretically 80 of each. Practical considerations, however, such as the number of markers that can be efficiently operated in a group and the maximum size office it is feasible to operate as a single administrative unit will limit an installation to about 60 incoming and 60 outgoing frames.

The sender link frame gives 100 trunks access to 40 senders.

2. *Senders.* Two separate groups of incoming senders are provided, one to receive DP and the other MF pulsing. Whether the system is installed in a step-by-step or a panel-crossbar area, both groups of senders always will be needed. MF will be received from senders in other CSP's and from switchboard positions. DP will be received from switchboard positions at TC's not equipped to send MF and in some cases from dialing A boards in the local area of the CSP itself.

Aside from the type of pulses received, the functions of the two senders are identical. They have a capacity for receiving and sending 11 digits. They must register arbitrary digits given them by the decoder and send them out as directed. They will send out digits by either the DP or the MF method as required to control switches in distant offices, and in some installations also will send digits to an outgoing sender in the same office by the d-c key pulsing method, which employs direct current in various combinations of value and polarity through a pair of conductors.

When the CSP is in a panel-crossbar area, a group of outgoing senders is provided to transmit either the type of pulses required by the equipment in local panel offices or the type used to reach manual offices.

3. *Markers.* The marker has been stripped of its usual translating functions and performs most of its duties on instructions from the decoder. It is told what leads to test for idle circuits and where they are to be found in the trunk block connector, but having found an idle circuit it carries on the process of setting up the connection independently of the decoder. Having contact with both the incoming and outgoing trunks through connecting circuits, it determines what frames they are located on, connects itself to those frames, selects a path through them, and sets up the connection.

In a single-train office one group of markers common to the office is provided. In a 2-train office there is a group of markers associated with each train of switches.

4. *Decoders.* A single group of decoders serves the entire office whether one or two trains of switches are provided. An important element of the decoder is the translator which will be discussed separately.

The decoder contains several hundred relays. A large group is used for registering the information furnished by

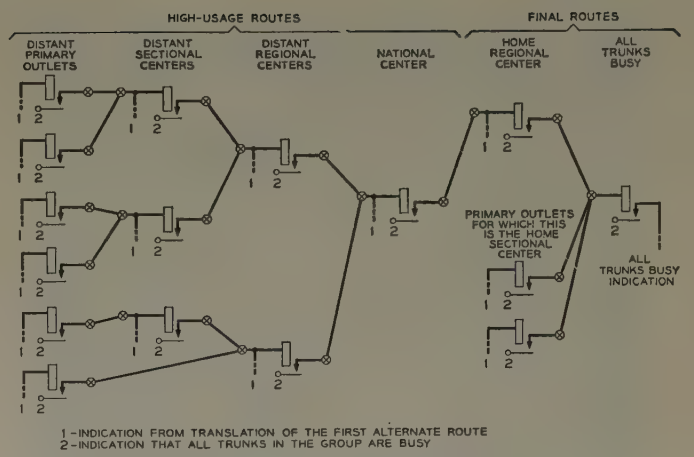

Figure 3. Alternate route array for the decoder at a sectional center

the translator. Others use this information to control the action of the markers and senders.

One group of decoder relays which is of particular interest is the array used for automatic selection of alternate routes. It is composed chiefly of one relay for each CSP to which the office has a direct group of toll lines. The relays are arranged in an orderly pattern simulating the pattern of the CSP network for the country as seen from the CSP concerned and are interconnected in a pattern of progression corresponding to the fixed order of alternate route selection. Group busy leads from the toll line groups are connected to the contacts of the relays in such a manner that if a group is busy the relay corresponding to the next choice route in the chain will be operated. In this way the lowest choice route having an idle circuit will be speedily selected without testing individual trunks of separate groups. The decoder learns from the translator which relay in the array to operate first and the choice of the best route available follows automatically. The principle will be readily understood by reference to the simplified sketch in Figure 3. Contacts not shown on the relays cause the translator to select the route corresponding to the last relay operated in the chain.

5. *Translators.* The magnitude of the translating job for nation-wide dialing led to the decision to develop a new translator operating on a principle radically different from that employed in other crossbar systems. In previous systems translation is done by relays. The code digits, never more than three, operate a group of relays which cause a single terminal corresponding to the code to be selected. A cross-connection is made between the code point and a route relay associated with the trunk group to be selected. The route relay has a number of contacts which are cross-connected to supply the information required for proper routing of the call. When changes in routing or equipment location of trunks within the office are made it is necessary to change cross-connections.

With the nation-wide dialing plan in operation, routing changes or opening of new offices in one part of the country will necessitate translator changes in many offices, some of them far removed from the scene of the event that forces them to be made. The changes in any one CSP will be

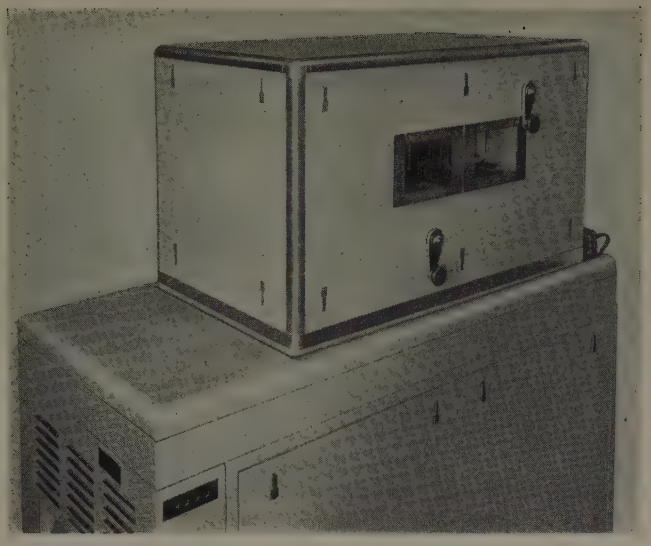

Figure 4. Card translator

frequent, therefore, and to make them by running cross-connections would be cumbersome and expensive. The new translator uses punched cards instead of relays, making it possible to effect changes by the simple process of removing old cards and inserting new ones in a machine. This can be done in a very short time and not only saves labor but requires less out-of-service time for the equipment. Figure 4 shows the machine.

A metal card about 5 by $10^{3}/_{4}$ inches is provided for each area code and also one for each office code that must be translated in a particular CSP, the cards representing destinations. The capacity of a single machine is about 1,000 cards. The cards are lined up in a box as in a filing drawer, with tabs along the bottom of the card resting on select bars which run the length of the box. A total of 118 holes are punched out in all cards in fixed positions so that in the normal condition 118 tunnels are formed from one end to the other. A light source at one end of the box shines through the tunnels upon phototransistors (Figure 5) at the other end but the phototransistors are disabled until, concurrently with the dropping of a card, voltage is applied to them.

All tabs along the bottom of the card are cut off except those which serve to identify the particular card. When a code is presented to the machine a combination of select bars corresponding to the code is lowered. The card having all tabs cut off except those resting on the lowered bars will drop but all other cards will remain in place. If nothing further were done the dropping of the card would cut off all light channels but on each card some holes are enlarged and through these holes the light continues to shine, energizing the corresponding phototransistors. The combination of enlarged holes furnishes all of the information needed for routing the call to the destination represented by the card.

Figure 6 shows the functions of the various groups of tabs and holes. The designations will not appear on actual cards. Figure 7 shows an actual card prepared for use.

(*a*). *Selecting tabs—input information.* The sole use of the information presented to the card translator is to enable it to select the proper card. The information presented is in the form of code digits with accompanying indications of their nature. The information is recognized by cutting off tabs along the bottom of the card in proper combinations.

The groups of tabs labeled *A*, *B*, *C*, *D*, *E*, and *F* are for the six code digits. For each digit used two tabs are left since the digits are registered in the sender on a two-out-of-five basis and the leads from the sender will operate the select bars directly. If the card represents an ordinary 3-digit code all tabs will be cut off except two each of the *A*, *B*, and *C* tabs, two of the four *CG* tabs, and perhaps either the *VO* or *NVO* tab. The *CG* (card group) tabs are used in combination to indicate 3-digit, 6-digit, and alternate-route card groups. The *VO* and *NVO* (via only and not via only) tabs are used when the group of toll lines over which the call will be routed is divided into one subgroup of a transmission grade suitable for only terminal traffic and another subgroup for either terminal or switched traffic. If the card represents an ordinary, 6-digit code two tabs will be left in each of the digit positions, and a different pair in the *CG* group.

(*b*). *Punch holes—output information.* The output information from the card translator is recognized in the decoder and marker by relays operated in the combinations set up by enlargement of associated holes in the card. The output from the phototransistors is amplified by other transistors to fire cold-cathode tubes which in turn operate the relays.

The pretranslation group on the top line of Figure 6 will illustrate the use of the punch holes. They indicate how many digits the sender must supply for a complete translation. The term "pretranslation" implies that further translation is required. This is not always true. In many cases only the first three digits need to be translated and all information needed for routing the

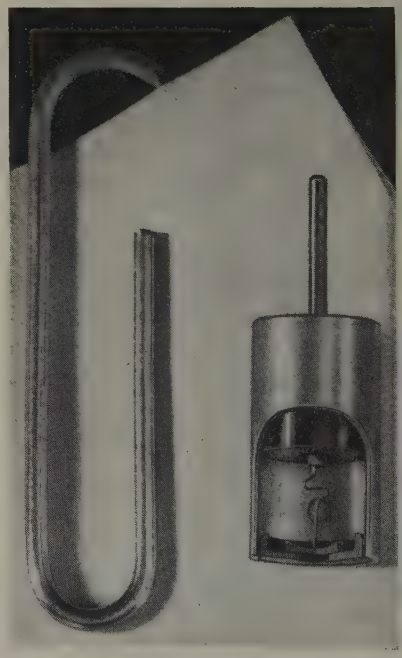

Figure 5. Cutaway view of a phototransistor, shown beside an ordinary paper clip

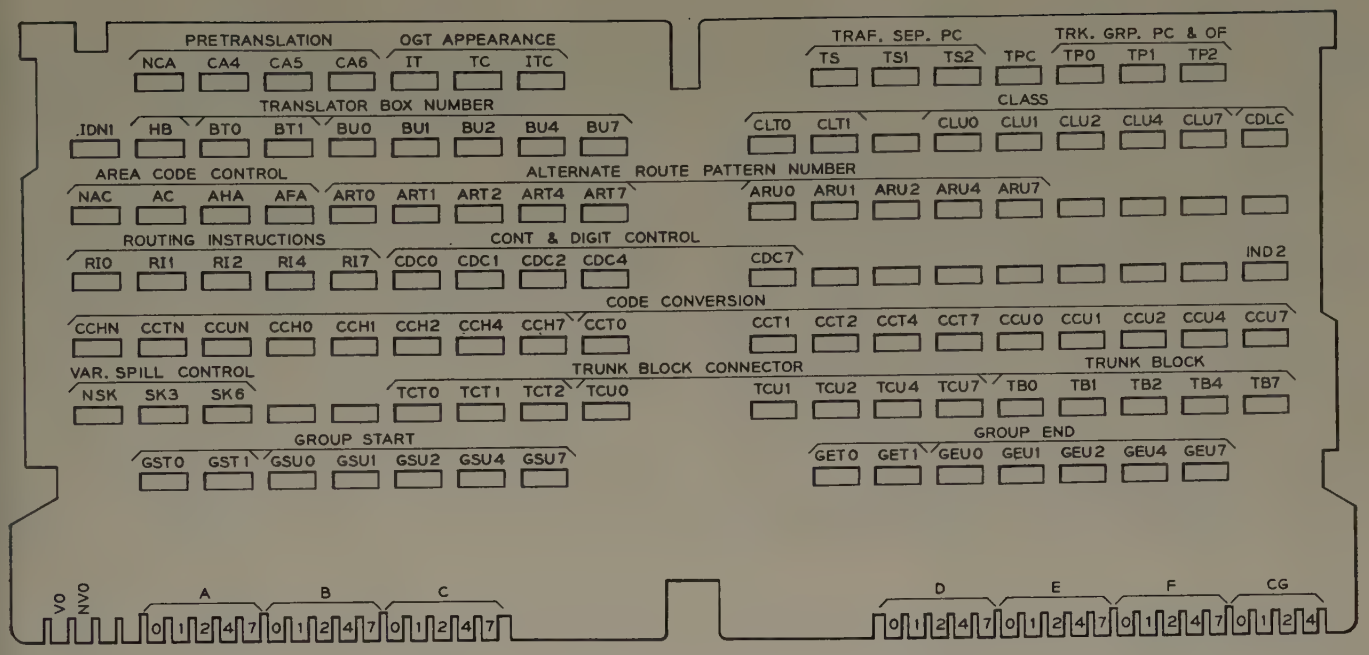

Figure 6. The layout of a card used in the translator

call is supplied by this card. In many cases the six digits of the area and office code are needed and the routing information will be on another card to be selected later. For certain calls such as calls to operators only four or five digits are needed. These are treated as 6-digit calls by having the sender supply the extra one or two digits to fill the complement. The *NCA* hole enlarged means "no come again"; that is, three digits are sufficient, and translation will proceed. The other holes enlarged mean, respectively, "come again when you have four, five, or six digits," and no further translation is done until the sender comes back a second time, probably to a different decoder, with an indication that it has the required number of digits.

An individual card is removed from the stack by first keying the code to cause it to drop so that it may be identified. Since a card can be located easily in this manner it is unnecessary to keep cards in any ordered position in the box.

At least one translator is provided in every decoder. It contains the cards for all offices in the home numbering area of the CSP, for certain operator codes, the single 3-digit card for each toll numbering area, and a card for each toll line group out of the office that can be used as an alternate route. If there are other areas to which the volume of traffic is very high and for which 6-digit translation is required the cards for those areas are put in a second machine in each decoder. Cards for other areas are put in foreign area translators common to the office and accessible to all decoders on a one-at-a-time basis. An emergency translator is provided to permit removal of all cards to it from any translator which may require prolonged repair work.

6. *Traffic Control Panel.* This panel is located in the operating room. The equipment in it consists of a key for each group used as an alternate route. When a particular key is operated no alternate routed traffic will be offered to the group represented by it nor to any group above it in the fixed alternate route pattern. This is do to relieve offices which are overloaded by either unforeseen or predicted traffic peaks.

MAINTENANCE

THE MAINTENANCE facilities for the new CSP system are basically similar to those of the older toll crossbar system with the necessary addition of equipment to test the new features introduced. The sender test frame is, of course, obliged to test the CSP features added to the sender and the trouble indicator frame is changed to operate with the new decoders, translators, and markers.

In place of the lamp trouble indicator the new trouble recorder introduced with the latest local crossbar system[7] is used. Whenever trouble is encountered it punches on a card a record of the circuits involved and of the important events that had occurred in the progress of the call, as an aid to the maintenance man in locating the trouble.

Automatic equipment for testing the operation and

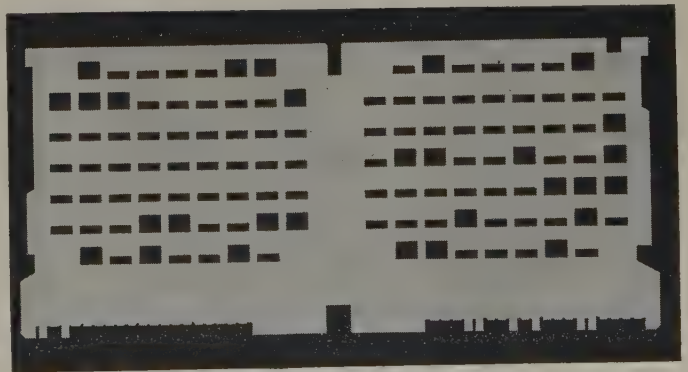

Figure 7. One of the punched metal cards with the identifying tabs along the bottom and some of the enlarged rectangular holes

transmission features of intertoll trunks has been designed also both for the older systems and for the new CSP system.

SWITCHING ASPECTS OF CUSTOMER TOLL DIALING

In the course of developing the switching system for CSP's the requirement for handling long-distance traffic dialed by customers, as well as that dialed by operators, was kept in mind. The trial of long-distance customer dialing now in progress in Englewood, N. J., confirms the soundness of the basic plan and exemplifies the principles involved in full realization of the plan. With a toll network laid out to accept a distinctive 10-digit number for any telephone in the country and route it to the proper destination, the remaining tasks to be performed are to provide for delivery of the number to the toll network from the customer's dial instead of from an operator and to provide an automatic record of the call for charging purposes.

In Englewood both tasks were quite easily performed. The Englewood local office equipment is of the most modern type[7] and includes Automatic Message Accounting (AMA)[8] facilities. When it was in the development stage the ultimate requirement for nation-wide customer dialing was foreseen and provision was made for expanding the digit capacity of the switching equipment at small expense. Also the designs of the accounting center were such that corresponding changes could readily be made. In the new local office switching system, arrangements were included for sending forward the complete number, as received, to the toll office by MF pulsing. The system was also designed to be capable of automatic alternate routing and this feature is used in the trial.

Expansion of the program will demand, of course, that similar arrangements be provided for the older types of local switching systems already in service. More extensive modification will be required to make them capable of giving the customer the same service. For them, as for the most modern system, however, AMA equipment is admirable for recording the information necessary for charging for the calls.

The requirement for customer toll dialing that senders (or directors) and recording equipment be provided has a bearing on the type of equipment used at TC's and TO's. For calls handled by operators and for calls received by the customers through such offices the only disadvantage of step-by-step equipment without senders at those points is that the CSP equipment at other points must be somewhat more complicated and expensive than it would need to be otherwise. But with customer dialing, if senders and recording equipment are not provided either in the local office or in the TC or TO, the calls must be routed by the most direct means possible to a CSP where such equipment is provided. Thus some advantage that might be gained from having them at the TC or TO would be lost:

1. In some cases an indirect route to the CSP would need to be taken for the sole purpose of recording the call. For example, a call which normally might be switched from a TC through a TO to another TC would need to be connected to the CSP for making the record.

2. There is no operator at the TC or TO to select an alternate route and with the equipment there incapable of automatic alternate routing the economies and service protection inherent in the alternate routing procedure would be lost.

If step-by-step toll switching equipment is already provided at a TC or TO, senders (or directors) could be added, making it in effect a common control switching system. This measure would permit automatic alternate routing and the further addition of recording equipment would eliminate the indirect routings for recording purposes.

A further benefit from having common control equipment in TC's or TO's can be realized in some instances. When a customer is served by a local office that has no senders he must dial one or more directing digits (probably three digits) ahead of the 7- or 10-digit number in order to get to an office where senders are provided. It is, of course, desirable to avoid this extra burden on the customer. Where the equipment in a TC or TO can be used in common for switching local and toll traffic, the customers whose lines are terminated in that office will be dialing directly into senders, if the equipment uses common control, and, therefore, will benefit in that they will not have to dial directing digits.

CONCLUSION

The new system was designed to implement the nation-wide switching plan, which integrates the switching network of the entire nation into a single unit. This switching job, requiring a high order of mechanical intelligence, is the most comprehensive ever performed by any system.

The skillful manipulation of code digits enables the provision of a numbering plan covering the entire country with a minimum number of digits to give each customer a distinctive number. It also obviates the need for extra expense to make step-by-step toll offices satisfactory operating elements of the plan in those locations where CSP features are not essential.

The automatic and almost instantaneous selection of alternate routes makes it possible to give virtual no-delay service without greatly increasing the cost of outside plant and to make multiswitch connections at a speed comparable to that for local service.

The translating equipment simplifies administration of the plan which demands co-ordination of activities on a nation-wide basis.

The numbering plan, the switching plan, and the CSP equipment which implements them make it feasible to offer nation-wide dialing service to customers without the aid of operators when automatic charging facilities and local office switching arrangements for handling the three extra digits of the national number are provided. It will be readily appreciated that so far as the CSP switching equipment is concerned, it is immaterial whether the digits it receives come from an operator or from a customer. The call will be routed to its destination and supervision for charging purposes will be furnished in the same manner in either event.

The new system represents an important step in the

process of continually improving the long-distance switching methods of the Bell System with consequent improvement of the service to all telephone customers in the United States and Canada.

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Safety Aspects of Grounding Portable Equipment

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THE PURPOSE of grounding exposed conductive materials enclosing electric equipment, or forming a part of such equipment, is to prevent potentials above ground on the equipment. Such potentials, if permitted, might cause passage of dangerous currents through the bodies of persons simultaneously contacting the live enclosures and the earth or grounded objects.

It is generally conceded that equipment grounding has little significant value as a safeguard against fire hazards. Grounding the frames and enclosures of such equipment may actually contribute to the fire hazard if it involves a sufficiently high resistance to prevent tripping or blowing of overcurrent protective devices.

Requirements of the Underwriters' Laboratories relating to the grounding of portable equipment are based on rules of the National Electrical Code, which is basically rules covering the installation of electric equipment in buildings. Part of the Laboratories' function is to determine that the listed electrical products can be installed in accordance with the Code's rules.

Grounding as a means of bleeding off static charges to prevent arcing and sparking is beyond the scope of this article. Equipment intended for use in hazardous locations is grounded to prevent arcs or sparks which might result from contact of the live frame or enclosure of the equipment with grounded metal objects, as well as to safeguard persons from electric shock.

The grounding of equipment as a safeguard against damage from lightning is not significant, although the grounding of the electric supply system to which the equipment is connected has been found to be a major safeguard.

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The degree of protection to be afforded by grounding is dependent, in part, upon whether the supply system is grounded or ungrounded. In this connection, the development of the concept of a grounded system in the National Electrical Code rules is worth noting.

SYSTEMS SUPPLYING INTERIOR WIRING

THE PRACTICE of grounding secondary distribution circuits on the customer's premises has not always been a mandatory rule of the National Electrical Code. The practice was first noted as a permissive one in the 1911 edition of the Code, and became mandatory in the 1913 edition. The rule stated that transformer secondaries of distribution systems must be grounded in such a manner that the maximum difference of potential between the grounded point and any point in the circuit did not exceed 150 volts. The rule for grounding of a-c systems in the 1951 edition of the Code is substantially the same.

The Code further provides that 2-wire d-c systems supplying other than industrial equipment in limited areas and operating at not more than 300 volts, shall be grounded. It is also required that the neutral conductor of all 3-wire d-c systems be grounded.

Prior to the wide use of underground cable and duct systems, considerable difficulties resulted from crosses between the low-voltage distribution systems and high-voltage lines, such as primary distribution lines, series arc-lighting circuits, and street-railway circuits. These crosses between the high- and low-voltage systems were often caused by

windstorms, line hardware failures, and insulation failures inside the distribution transformer. Such crosses were recognized as sources of fire and electric shock hazards.

Fires were also commonly caused by lightning discharges seeking paths to ground through the low-voltage distribution wiring system.

In addition to the troubles resulting from crosses and lightning, difficulties also resulted from the impracticability of permanently insulating all conductors of the system from ground. Numerous accidents occurred, wherein workmen, feeling that they could work on energized equipment with reasonable safety, received fatal shocks when they contacted live parts and completed the electric circuit through their bodies back to some unintentional ground which existed on the system.

It was in consideration of these factors that the grounding of systems supplying interior wiring became a mandatory provision of the National Electrical Code. The Code states that circuits are grounded for the purpose of limiting the voltage upon the circuits which otherwise might occur through exposure to lightning or other voltages higher than that for which the circuit is designed, or to limit the maximum potential to ground due to normal voltage.

To realize any measure of protection from a grounded system, it was apparent that overcurrent protective devices which would open in the case of accidental grounds should be provided in the ungrounded conductors, and that no such current-interrupting devices should be located in the grounded conductors, but that special precautions should be followed to insure the continuity of the grounded conductors. It was further evident that the resistance to ground should be so low as to prevent an appreciable rise above ground potential of the grounded conductor when current flowed in the circuit.

The first attempt to deal with the grounding of portable equipment appeared in the 1928 edition of the Code. The requirement stated that portable equipment operating at potentials greater than 150 volts to ground, used in industrial establishments, and having exposed metal parts, should be grounded by means of a multiprong attachment plug cap having one prong electrically connected to a corresponding grounded contact of the outlet. Industrial plants were defined as those buildings or parts thereof where persons were employed in manufacturing processes or material handling as distinguished from dwellings, offices, public utilities, and like occupancies.

Apparently, those provisions were difficult of enforcement or were deemed unduly severe, because the 1930 edition modified the rule to indicate that the exposed noncurrent-carrying metal parts of portable equipment need be grounded only in the case of: 1. portable motors, which operated at more than 150 volts to ground; and 2. portable lamps or other portable current-consuming devices in hazardous locations.

While there were minor changes in the intervening editions, the next significant changes, with respect to grounding of portable equipment, appeared in the 1940 Code. The requirement stated that exposed noncurrent-carrying metal parts of portable equipment should be grounded: 1. if used in hazardous locations; 2. if operated at more than 150 volts to ground except (*a*) motors if guarded, (*b*) metal frames of heating appliances which might be permanently and effectively isolated from ground, and (*c*) enclosures for X-ray tubes used in therapy; and 3. in other than residential occupancies, where such equipment is used in damp or wet locations, or by persons standing on the ground or on metal floors, or working inside metal tanks or boilers, except where supplied through an insulating transformer with ungrounded secondary of not over 50 volts.*

The 1940 and 1947 Codes required that the metal frames of electric ranges be grounded by any of the means recognized for grounding of portable equipment or by grounding the frame to the grounded circuit conductor. This development represented the first time that appliance grounding to the grounded neutral-circuit conductor had been permitted. Although the domestic electric range does not generally employ voltages greater than 150 volts to ground, the code-making authorities deemed it desirable to ground the metal frame because of the large surface area of exposed metal which could be contacted, because of the numerous contacts with this exposed metal, and because it was considered impractical to isolate the frame from ground. In recognizing the connection to the grounded neutral conductor, the code-making authorities considered that most ranges employ 120–240-volt 3-wire systems, and grounding would be automatically accomplished whenever the device was energized.

The 1947 Code also required that at least one 3-pole-type receptacle designed for grounding of laundry appliances be provided in each dwelling occupancy. The rule undoubtedly had as its objective, the provision of means for grounding of portable domestic washing machines. However, it was realized that, because of the large number of 2-pole receptacles already installed, it would not be practicable at that time to require that all washing machines be similarly provided with 3-pole attachment plug caps. The Code did not then, and does not now, require that domestic washing machines be grounded. It was apparently hoped that, at some future date, these receptacles would be so common that 3-pole caps could then be required on supply cords of all domestic washing machines. In the meantime, the provision for grounding at the washing machine outlet makes it possible for such machines to be effectively and automatically grounded each time the appliance is employed if the user wishes to attach a 3-pole cord and plug for this purpose.

The other requirements for grounding of portable equipment as given in the 1940 edition remained practically unchanged and the 1951 edition embodies these rules.

Although this article is concerned with the grounding of portable equipment, an examination of the Code rules for the grounding of fixed equipment may assist in understanding the basic concepts of grounding of equipment where such grounding can be effectively and practically accomplished.

The general rule for grounding of fixed equipment states that under any of the following conditions, exposed non-

* This requirement is contained in paragraph 2545 of the 1951 Code. A proposal to lower the 50-volt value is being considered by Code-Making Panel Number 5.

current-carrying metal parts of fixed equipment, which are liable to become energized, shall be grounded: (*a*). if equipment is supplied by means of metalclad wiring; (*b*). if equipment is located in a wet location and is not isolated; (*c*). if equipment is located within reach of persons who can make contact with any grounded surface or object; (*d*). if equipment is located within reach of a person standing on the ground; (*e*). if equipment is in a hazardous location; (*f*). if equipment is in electrical contact with metal or metal lath; and (*g*). if equipment operates with any terminal at more than 150 volts to ground except metal frames of electrically heated devices which may be exempted by special permission if the frames are permanently and effectively insulated from ground.

The foregoing rule embodies a number of fundamental concepts. One of these is that metalclad wiring, although out of reach of persons, might contribute toward making the exposed metal parts of equipment live due to insulation failure within a raceway where the raceway itself may not be effectively grounded.

Another concept contained in this requirement is that the presence of exposed noncurrent-carrying metal enclosing electric equipment in the vicinity of plumbing and other piping systems makes it desirable that there should exist no difference of potential between such metal parts. For this reason, the use of a water piping system for grounding is required wherever such system is available.

Several provisions of the requirement are based upon the concept that guarding and isolation are equivalent to grounding as a protective measure against electric shock. Several provisions recognize that the shock hazard is greatest when a person is standing on the earth, in wet locations in contact with the earth, or is apt to contact grounded surfaces or objects simultaneously with contact of the equipment.

The provision that fixed equipment be grounded if in contact with structural metal or metal lath is based on prevention of random grounds wherein currents resulting from faults or other causes returning over such metal might raise its temperature as to become a fire hazard.

The provision that equipment be grounded if it operates with any terminal at more than 150 volts to ground, except isolated or guarded heating appliances, is predicated on the fact that there are few circuits in residences operating at more than 150 volts to ground, and the realization that grounding of equipment used on such circuits is not practicable. The rule is not intended to imply that all voltages less than 150 volts are nonhazardous. The provision recognizes, however, that the shock hazard increases as the voltage increases.

METHOD OF GROUNDING PORTABLE EQUIPMENT

THE EXPOSED noncurrent-carrying metal parts of portable equipment may be grounded by any of the following ways:

1. By means of the metal enclosure of the conductors feeding such equipment, provided an approved multiprong plug or equivalent is used, one prong for the purpose of grounding the metal enclosure, and provided further that the metal enclosure is attached to the plug and to the equipment by connectors which are approved for such purposes.

2. By means of a grounding conductor run with the circuit conductors in cable assemblies or flexible cords. provided an approved multiprong plug or equivalent is used, one prong for the purpose of connecting such grounding conductor to the grounded metal raceway or cable armor. This conductor may be uninsulated, but if an individual covering is provided for this conductor, it shall be finished to show a green color.

3. By means of a separate flexible wire or strap, insulated or bare, protected as well as practicable against mechanical injury.

If a grounding conductor is a part of an approved flexible-cord assembly, the attachment to the frame or the enclosure of the equipment should be made in such a manner as to be independent of assembly screws or other means which may impair the effectiveness of the connection in the normal process of servicing or using the equipment. The connection preferably should be made by means of a machine screw or the like to facilitate reconnection of the grounding conductor at the time the supply cord is replaced. All exposed noncurrent-carrying metal parts of the equipment which may become live and contacted by persons should be metallically bonded.

Where a separate conductor is used for the purpose of equipment grounding, a suitable type of pressure-wire connector attached to the exposed metal noncurrent-carrying parts is considered to meet the requirements.

In the grounding of portable equipment, the size of the grounding conductor may be number 18 or 16 American Wire Gauge copper when used as part of an approved flexible-cord assembly, provided further that the fuses or circuit breakers in the supply conductors are set or rated at not more than 20 amperes. A number 14 American Wire Gauge copper conductor may be employed for grounding equipment which can be operated on circuits wherein the overcurrent device is rated or set at not more than 30 amperes.

GROUNDING CONNECTION AT OUTLET

THE GREATEST PROBLEM in connection with the grounding of portable equipment, and particularly domestic appliances, arises in connection with effectively completing the grounding circuit at the supply outlet.

In the development of the use of electric energy for light and power purposes, the Edison screw-shell lampholder-type receptacle and the Edison screw-shell attachment plug cap preceded the present design of parallel slot receptacles and parallel blade caps. These early designs were 2-pole devices and it followed that the common wall receptacle and attachment plug cap were also 2-pole devices. The result of this growth and development is that the millions of 2-pole receptacles presently installed do not lend themselves to use in making connection with attachment plug caps wherein grounding will be automatically accomplished when the caps are inserted. This set of circumstances has made the question of grounding of portable equipment a riddle which still defies solution to a very large degree.

Many attempts have been made to solve this problem

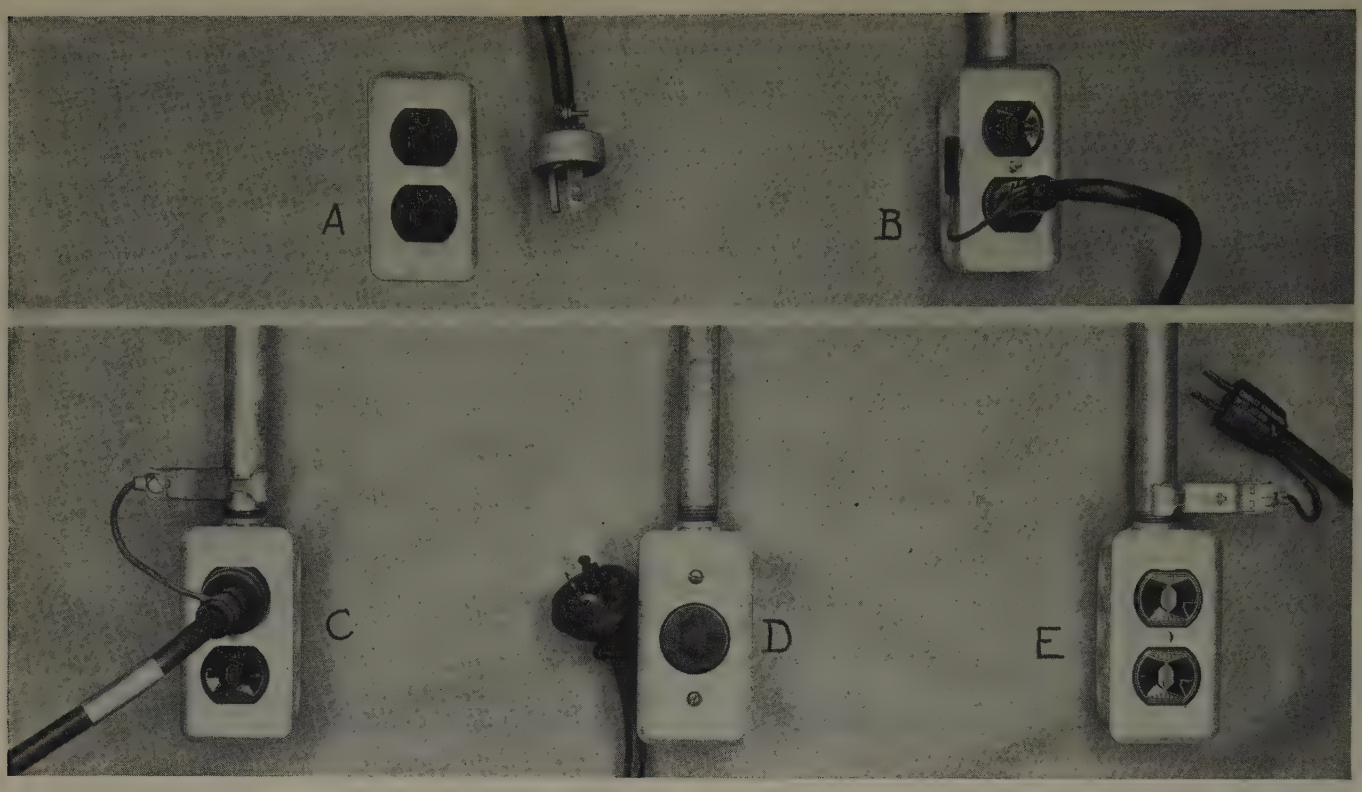

Figure 1. Common grounding terminations for portable equipment: A, new ASA grounding cap and receptacle; B, plug-and-jack-type connector; C, battery-clip type of connection; D, 3-pole receptacle and cap having one radial blade for grounding; E, plug with battery-clip-type connector showing proper sequence of connection

by the use of adapters and certain types of pigtail terminations on the grounding conductor. However, in all such uses, the human element is to be considered in establishing the continuity of the grounding circuit, since none of these means accomplishes it automatically.

A receptacle and plug intended primarily for equipment grounding have been developed recently. See Figure 1*A*. This receptacle and plug, which have been adopted as American Standards, were designed to overcome many of the deficiencies of existing grounding means as noted in the Article 250 (National Electrical Code) Committee Report on Grounding of Portable Equipment. The receptacle will accommodate existing 2-pole parallel-blade-type attachment plug caps, or will accommodate a 3-pole attachment plug cap which has a round or half-round grounding blade. Because the receptacle is able to accommodate existing parallel-blade attachment plug caps, one of the stumbling blocks in the way of grounding portable equipment is removed in that its use does not make obsolete all existing equipment provided with 2-pole parallel-blade caps. The use of this receptacle and plug has two additional advantages in that grounding is accomplished automatically, and in that the design does not accommodate 3-pole caps wherein all poles may be energized.

There have been various arrangements of the pigtail termination which have been recognized as suitable grounding means in connection with approved flexible-cord assemblies. One of these is the plug-and-jack type of connector wherein the male portion of the plug is intended to replace the receptacle face-plate screw and the telescoping female portion of the connector is permanently attached to the grounding conductor of the supply cord. See Figure 1*B*. Another is the use of a battery clip on some types of equipment such as industrial tools. Recognition of this type of grounding termination contemplates that such equipment will not be used at the same outlet on a day-to-day basis, but that exposed conduit or water piping would be readily accessible for connection. See Figure 1*C*.

Spade-type lugs with upturned ends and hook-type lugs also have been recognized types of grounding terminals. With these arrangements, grounding may be effected at any point on a metal raceway where a machine screw, under which the lug can be inserted, is available. These types of terminations, while not readily detachable, can be used at any location where receptacles are mounted on grounded metal outlet boxes, as such mounting invariably involves the use of machine screws.

One of the weaknesses of the pigtail type of termination is that it does not lend itself readily to use with extension cords. For this reason, such terminations are not recognized as suitable on gardening appliances and the like. It is expected that these appliances will invariably be supplied through extension cords. On such appliances, only the multiprong type of attachment plug cap, having one prong intended for equipment grounding, is recognized as suitable. See Figures 1*A* and 1*D*.

There are available, corresponding multiple cord connector bodies for assembly on flexible cords which permit the automatic establishment of the continuity of the grounding circuit through the extension cord.

An alternative to the pigtail type of grounding termination is the use of a multiprong attachment plug and receptacle having one prong for equipment grounding. This type of grounding connection has one major advan-

tage over other types in that grounding is accomplished automatically each time the attachment plug is inserted. On the other hand, it has one very serious disadvantage in that the majority of presently installed outlets are 2-pole rather than 3- or 4-pole types. In deciding whether the use of 3-pole caps should be the only recognized means for grounding 2-wire portable equipment, consideration should be given to conditions existing in the field. Because the overwhelming majority of existing receptacles with which appliances are used are 2 pole, the provision of a 3-pole cap on such equipment is likely to invite replacement by persons who may not be familiar with the intended purpose of the grounding conductor. Improper connection can create the conditions which grounding attempts to prevent should the grounding conductor be attached to one of the live terminal screws.

The 3-pole receptacle having one radial slot for grounding, and a 3-pole cap having a corresponding blade for grounding (Figure 1*D*) have one other disadvantage in that they have been widely used for supplying 3-phase circuits and 3-wire Edison systems, as well as 2-wire systems with equipment grounding. Because of such a variety of uses, it is to be expected that there occasionally will be accidents because an appliance intended to have a grounded frame is plugged into a receptacle, all poles of which are at a potential above ground.

Another factor to be considered in the grounding termination is the proper sequence of making the connections. In the event of defective insulation or live enclosure from other causes, any measure of protection to persons will involve the grounding of the enclosure prior to energizing the device. None of the pigtail-type terminations in any way guarantees that this sequence of connections will be followed. On certain types of equipment involving the use of pigtail-type terminations for grounding, caution markings, calling attention to the fact that the grounding connection is to be made prior to insertion of the attachment plug cap, have been required. See Figures 1*C* and 1*E*.

An evaluation of some of the common grounding terminations is given in Table I.

In view of some of the obvious weaknesses of the pigtail-type termination, its recognition might well be questioned. Justification for recognition seems to be based on the fact that the supplying of a multipole attachment plug cap on portable equipment by no means is a guarantee that the user will provide a similar multipole receptacle to accommodate such cap. Instead, the user has been known to replace such caps with 2-pole caps and to connect improperly the grounding conductor, thereby creating the hazard which equipment grounding seeks to prevent.

An additional factor to be considered in the over-all evaluation of equipment grounding, particularly as it relates to domestic appliances, is the inability of the average user to determine whether or not the point of connection of the grounding termination at the outlet is effectively connected to ground. Metallic outlet boxes connected by nonmetallic-clad wiring may be isolated from ground, and nonmetallic boxes enclosing attachment plug receptacles are not normally provided with separate means for grounding. It is obvious that the attachment of the grounding termination to such isolated boxes would not afford any measure of protection against electric shock.

The proposition has been advanced that most of the difficulties encountered in the effective grounding of portable equipment could be overcome simply by mandatory use of only polarized 2-pole receptacles and plugs wherein the enclosure would be connected to the polarized (grounded) terminal. Such a proposal overlooks the fact that there are many receptacle outlets which are not polarized, and that to make use of such outlets requires only that the width of the polarized blade of the attachment plug cap be reduced, or a nonpolarized type be substituted. Under such conditions, the enclosure has an even chance of being live at all times. Another objection to such a proposal is that any opening of the circuit of the grounded conductor would make the enclosure live at full-line potential whenever the equipment is plugged into the receptacle.

CONNECTION OF GROUNDING CONDUCTOR TO EARTH

THE ACTUAL CONNECTION of the grounding conductor to the earth, while not pertinent to the design or manufacture of equipment, determines, to a large extent, the level of protection provided. The entire grounding circuit should have a sufficiently low resistance to insure enough current to operate promptly overcurrent protective devices, and thus remove the source of hazardous potential. The low resistance also insures that, when current is flowing in the grounding circuit, the connected equipment is not raised appreciably above ground potential.

For a 120-volt circuit protected by a 30-ampere overcurrent device, a resistance of less than 3.6 ohms is required, since 30-ampere rated overcurrent devices will carry 10-per-cent overload continuously without operating. While

Table I. Evaluation of Different Grounding Terminations for Various Conditions of Use

	Grounding Terminations for Portable Equipment						
	Battery Clip	Plug and Jack	Eyelet	Spade Lug, Upturned Ends	3-Pole Attachment Plug Cap, 1 Radial Blade	3-Pole Attachment Plug Cap, 2 Parallel and 1 Round Blade	Pigtail Lead Only
Automatic use	No	No	No	No	Yes	Yes	No
Use with existing outlets	Yes	Special screw	Yes	Yes	3-pole only	3-pole only	Yes
Use with extension cords	No	No	No	No	Yes	Yes	No
Readily detachable	Yes	Yes	No	No	Yes	Yes	No
Proper sequence of connections	No	No	No	No	Yes	Yes	No
Misuse	No	No	No	No	Yes*	No	Yes**

* 3-pole caps and receptacles of this design are commonly used for 3-phase connection.

** Unsecured grounding wire with no termination increases likelihood of connection by the user to a live terminal screw.

no specific reference is made in the National Electrical Code to the maximum value of resistance permitted for grounding of equipment or systems, the Code does state that a metallic underground water-piping system always shall be used as the grounding electrode where such a piping system is available. This Code further states that, in general, continuous underground water-piping systems have a resistance to ground of less than 3 ohms. Other Codes indicate the resistance of water pipe grounds ordinarily to be less than 0.25 ohm. The resistance of the connection to earth generally constitutes the chief resistance in the grounding circuit, and this value should be as low as practicable.

The Code implies that where driven grounds employing "made electrodes" are used, the resistance to ground should not exceed 25 ohms if practicable. This value of resistance, while not offering a sufficiently low-resistance path to ground likely to cause operation of the overcurrent protective devices on 30-ampere 120-volt branch circuits, does afford a measure of protection against crosses between the primary and secondary of the distribution transformer in that it will result generally, at the higher primary voltage, in sufficient current flow to cause tripping or blowing of the primary overcurrent protective device of the transformer.

HAZARDS INTRODUCED BY EQUIPMENT GROUNDING

No discussion of the subject of equipment grounding would be complete if it presented only the view that, under all conditions, grounding was positive assurance against fires or against injury to persons.

In the case of a high-resistance grounding connection the actual potential of the enclosure of the equipment may be raised to a dangerous value above ground potential, the overload protective devices may not operate, and the supply conductors may be overloaded as a result of fault currents.

Quite aside from the introduction of hazards because of high resistance of the grounding connection, is the introduction of certain hazards because of low resistance of the grounding connection. The Article 250 Committee Report on Grounding of Portable Equipment pointed out that many accidents were caused directly by the presence of well-grounded metal in contact with persons using the equipment. Approximately 25 per cent of the shock cases reported in this study were caused by persons touching live current-carrying parts. Under such conditions, the presence of grounded metal, as against isolated metal, contributes to the establishment of conditions necessary to cause a shock to persons. Exposed live portions on flexible cord connecting equipment employing grounded enclosures establish conditions for severe electric shock to persons using or handling the equipment.

Indirectly, mention has been made previously of increased shock hazards due to the provision of grounding means in the supply cord of portable equipment. These hazards result from: 1. use of multiprong plugs in receptacles wherein all contacts are energized; 2. malalignment of blades of plugs to permit insertion into receptacles in such a manner that the enclosure of the equipment is made live; 3. contact of the pigtail connection with a live prong of the attachment plug cap in such a manner as to make the enclosure live; and 4. the substitution of 2-pole for 3-pole plugs in such a manner that the grounding conductor is connected to a live terminal screw.

Mention already has been made of the potential hazards of servicing energized equipment where there is possibility of live tools coming in contact with grounding metal parts of the equipment. Additional hazards of arcing and burns to service personnel are introduced.

CONCLUSIONS

The grounding of portable equipment is a safety measure intended primarily to prevent the existence of a potential above ground on the exposed noncurrent-carrying metal parts which might cause electric shocks to persons handling or coming in contact with such equipment.

A comparable measure of protection might be secured in certain instances by the use of other methods, such as insulation, isolation, and guarding.

The level of protection to be afforded by equipment grounding is dependent upon the reliability of the grounding means employed, its usability under conditions apt to be met with in the field, and the over-all resistance value of the grounding connection.

The details of provisions to accomplish the protection anticipated by the grounding concept are given in the National Electrical Code. The effective grounding of portable equipment, particularly domestic appliances, remains unsolved primarily because of the lack of an automatic means of accomplishing grounding in the vast majority of applications involving the use of 2-pole receptacles.

Grounding does not always insure the greatest measure of protection to persons and, under certain conditions, actually may increase that hazard.

Isolating or guarding the exposed noncurrent-carrying metal parts of a machine or equipment which must be serviced while energized, together with isolating the operating personnel from ground, is generally recognized to afford a higher degree of protection than can be accomplished by grounding.

In cases of equipment involving large areas of exposed metal, or where the user is apt to be in contact with the earth, either directly or through use of the equipment in a wet location or through grounded metal, and where grounding can be effectively accomplished, it contributes to a high level of protection for persons against electric shock.

Grounding is not intended as a substitute for proper spacings, adequate dielectric strength tests, or the use of proper insulating materials, but is a supplemental safety measure to all these features.

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Annual Carrying Charges

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IT IS ADMITTEDLY difficult to anticipate future variations in some of the factors involved in economic studies, such as taxes and probable life, just as it is difficult for the transmission-line designer to anticipate future loads and power factors. But in neither problem is the correct arithmetic a matter of personal judgement; the arithmetic of economic comparisons is as rigorous and clear-cut as Ohm's Law. This article deals with the appropriate treatment of return on the investment, depreciation, taxes, and insurance.

Rate of return in any given year equals the ratio a/b, where a = interest paid plus earnings available for dividends, and b = capitalization of the enterprise in the given year.

The estimate often is derived conveniently from the adjudicated rate of return on the rate base, but the latter is commonly less than the rate applicable to first cost, and the rate therefore must be adjusted accordingly. Two major reasons for the difference between rate base and first cost are the effect of rising price levels, and the treatment of depreciation reserves.

It is necessary to recognize the risk involved in reinvesting reserves in the enterprise, or the increased costs that result from alternative investment in other securities. The recommended procedure is to derive the true rate of return on first cost, plus the depreciation annuity resulting from reinvestment of reserves at that same rate.

Annual cost of depreciation is a function of average life, the type of retirement dispersion, net salvage, and the rate of return. No judgement is involved in deriving the annual cost, in per cent of first cost, from estimates of these four quantities; the method of accounting for depreciation is immaterial.

Authoritative treatises on methods of estimating service life are now available. Dispersion patterns are classified conveniently according to the Iowa Type Curves. Tables and curve sheets permit quick determination of the annual cost for any life, dispersion pattern, or rate of return.

They present depreciation annuities for returns of 5, 6, and 7 per cent, and average lives from 10 to 50 years.

Within the past decade, important advances have been made in the art of preparing life estimates. The most recent and most useful development is the simulation procedure, which utilizes data ordinarily available from the books of account, reveals both average life and type of dispersion, and provides means for testing the trustworthiness of estimates. On occasion, the investigator may be willing to estimate average life, but may lack any basis for anticipating the type of dispersion. In such case, the probable limits of estimate are quite narrow, since most experience seems to lie within the range of S_0 to S_2, or R_1 to R_3. An arbitrary estimate within this range is far superior to the common assumption of no diversity, which is virtually never justified.

Even when estimating depreciation costs of a single unit, it is necessary to allow for dispersion typical of the group to which it belongs. If the unit is the only one of its kind, and its group behavior therefore indeterminate, assumption of type S_2 dispersion will reflect the approximate effect of normal probability.

Net salvage is usually a small percentage, and reasonably predictable. Removal costs usually exceed gross scrap value for buildings, generating equipment, switchboards, control equipment, poles, and towers, which increases the depreciation annuity.

"Straight-line" depreciation as sometimes performed, by assuming a level annual cost equal to original investment divided by average life, is a gross error in arithmetic that does not reproduce the actual bookkeeping. "Straight-line" costs are not a uniform annual percentage, but decrease each year from a high initial rate, commonly becoming a negative charge in later years. Their computation, for economic comparisons, is unduly laborious; their application to practical problems extremely awkward. The simpler present-worth group-basis annuity may be regarded as the weighted average of "straight-line" costs. Precisely the same answer to economic problems is obtained by use of either method, correctly done.

A different treatment is required for each of four varieties of taxes: income taxes, gross receipts taxes, real-estate and capital-stock taxes, and payroll taxes.

Estimates of future income taxes present the greatest difficulty, but they may be expressed as a percentage of first cost by means of a simple formula. It is incorrect, as sometimes proposed, to omit them from economic comparisons. It is also incorrect to assume that the Federal Government pays a part of incremental maintenance costs because such expense reduces net income and therefore reduces the tax.

Premiums paid to insure specific plant should be expressed as a percentage of original investment cost, not of "firm value" or other insurable base. Much insurance, such as public liability and fidelity bonding, is unaffected by the choice of alternatives, and may be ignored for the present purpose.

Annual carrying charges, poorly described as "fixed charges," are estimated conveniently as a percentage of first cost of investment. This article describes appropriate methods of estimate for the purpose of forecasting annual revenue requirements—the criterion of economy—which must be sharply distinguished from the rate-making process of allocating current costs on a nondiscriminatory basis.

Digest of paper 51-358, "Annual Carrying Charges in Economic Comparison of Alternative Facilities," recommended by the AIEE Committee on System Engineering and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Published in AIEE *Transactions*, volume 70, part II, 1951, pages 1942–53.

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Tensorial Analysis of Transmission Systems—II

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THE FIRST PART of this series[1] introduced new measurements and a new set of equations $\mathbf{L}=\mathbf{MP}$ to express the performance of a transmission system in terms of real generator powers **P**. The equations may be used, among others, for I^2R loss calculations and economic loading studies. The results of Part I may be generalized in two different directions:

1. The assumptions about the operating behavior of a single division are generalized.
2. Several divisions are interconnected through tie lines and information is desired about each division and about the total system.

The purpose of this article is to introduce the first more exact assumption about the operating behavior of a single transmission system over and above the absolute minimum employed in Part I. In many transmission systems the transformers have actual turn-ratios that differ from the ratios of nominal values assigned to the different voltage levels of transmission. These deviations are represented on the a-c analyzer by autotransformers. Similarly, the autotransformers of an actual system are represented themselves on the analyzer by autotransformers.

Numerous calculations have shown that in I^2R loss calculations the most important factor is the scalar value of generator currents. Quantities whose variations do not change these scalars, such as the reactive currents, may be ignored or considered only by a crude approximation. Such a situation arises, for instance, with synchronous condensers whose currents are purely reactive. The latter may be lumped together with the load currents since their influence upon the scalar value of generator currents is small. On the other hand, the autotransformer ground currents have large active components that do not vary with the load, especially when an autotransformer is located near a generator. Hence, it is necessary to develop a special method to consider the influence of autotransformer ground currents even when only I^2R loss calculations are considered.

Ward, Eaton, and Hale[2] also have considered the existence of these currents. The results of the present treatment are identical with theirs, except that the approach here is different. The theory of autotransformer currents is so formulated in this article that these currents may be introduced, or left out at will, with any type of assumption, without disturbing the train of thoughts required by the various more exact assumptions themselves, and without changing the method of measurements.

The theory to be presented is connected intimately with the concept of viewing the transmission system as a junction network. In contrast to that, a hypothetical autotransformer current will be assumed to circulate in an arbitrary closed mesh. The accompanying problem is threefold:

1. To select the most suitable circulating mesh for each type of junction pairs (physical frames) assumed.
2. To eliminate the permanently short-circuited mesh from the physical view and from the equations; that is, to decrease the number of equations by one.
3. To keep the simplified equations as tensor equations; that is, to allow the reduced **E**, **Z**, and **I** to obey the laws of transformation of tensors.

The nature of the autotransformers is such that on the a-c analyzer they must be grounded permanently. Hence, in measuring self- and mutual-leakage reactances between the junction pairs, the points of entry of the autotransformers cannot be open-circuited.

However, for analytical purposes only, the existence of an open-circuit condition will be assumed also. A transformation from the theoretical open-circuit to the actual short-circuit reference frame will indicate how to handle the numerous permanently short-circuited conditions that may be assumed.

The effect of the presence of autotransformers upon the measurement and calculation given in Part I is surprisingly slight. It is shown that:

1. The measurements remain identical.
2. Only one of the matrix of transformation $\mathbf{C}_3^2$ assumes a slightly more complex form; the unit components in the last row are replaced by real numbers.
3. The impressed voltage vector (not used in loss problems) assumes a more general form.

In later studies, when entire systems will be interconnected or replaced by equivalent circuits, again it will be found that the presence of autotransformers has only a slight influence upon the method of measurements and also upon the procedure in the calculations. Nevertheless, to be able to arrive at such a simple solution of the otherwise considerable autotransformer difficulties, it will be necessary to go through a rather roundabout and detailed, but systematically organized, reasoning.

A numerical example of the transmission loss study in a system with off-nominal turn-ratios is given by Kirchmayer and McDaniel.[3]

Digest of paper 52-111, "Tensorial Analysis of Integrated Transmission Systems, Part II—Off-Nominal Turn Ratios," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21-25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Further Data on the Design of Eccles-Jordan Flip-Flops

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The design of a prototype Eccles-Jordan flip-flop as used in large-scale digital computers is discussed, stressing the role of component variability. A graphical design technique is given, which should prove helpful in other switching circuit design problems using a large number of identical direct-coupled circuits.

IT IS COMMON knowledge that the bistable vacuum-tube device referred to as the Eccles-Jordan flip-flop was first described by Eccles and Jordan in 1919.[1] It is perhaps not so well known that the device described by them is not identical with the current flip-flop in that they used batteries in the place of transpose resistors and thus dispensed with resistor divider networks.

The flip-flop now in common use is shown in Figure 1. It consists of the following: two divider networks each containing a plate resistor R_1, a transpose resistor R_2 usually shunted by a transpose capacitor C_2, and a grid resistor R_3; two tubes, either triodes or pentodes; and two supply voltages, one positive and the other negative with respect to the grounded cathodes. Variations of this configuration are in use; note in particular that it is not necessary that the two halves of the flip-flop be nominally identical. This article is restricted to the illustrated circuit.

Figure 1 illustrates one stable state in which the left tube is completely cut off while the grid voltage of the right tube is slightly above ground. A. T. Starr[2] showed that stability can be attained even though the "off" tube is not cut off and the "conducting" tube has negative grid. In fact, it is easy to show that stability requires only that, in the quiescent state, the loop gain around the two tubes be less than unity. On the other hand, it is advisable to protect against malfunctioning due to "noises" and therefore to reduce the loop gain by ensuring both cutoff for one tube and grid conduction for the other. In any case it should be noted that a variation in any parameter which increases the grid voltage of the cutoff tube or decreases the grid voltage (or current) of the conducting tube leads the flip-flop closer to instability; this criterion will be used in the following to determine the influence of parameter variations on flip-flop stability.

The design of a single Eccles-Jordan flip-flop for laboratory use is relatively simple and straightforward. On the contrary, the design of a prototype flip-flop to be used, for example, in a large-scale digital computer requires more care because of the large number of flip-flops involved. First, the flip-flop must fit into the framework set by other computer circuits, which implies specified output voltage levels and switching times. Secondly, the flip-flop must exhibit the desired characteristics in spite of component variations, both initial and during use in the machine. In this respect, attention must be focused on resistor drift, tube aging, and fluctuations in supply voltages.

The general problem of flip-flop design with all its ramifications is much too complex to permit of its discussion here. Hence, the following assumptions are made in order to restrict and define the scope of the article:

1. All resistors will be so selected that after long service in the computer they will not drift outside a given fractional tolerance, ρ, from nominal resistance.
2. All supply voltages can be held at all times to within a given fractional tolerance, σ.
3. Knowledge of the tube characteristics for the complete life of every tube, or tube rejection criteria, are such that (*a*) plate current i_p for zero grid voltage e_g and specified plate voltage e_p will always exceed a known value, and (*b*) grid bias for given e_p need never exceed a known value to ensure cutoff.
4. Satisfactory operation is ensured if (*a*) tube cutoff is ensured, (*b*) the grid of the conducting tube reaches at

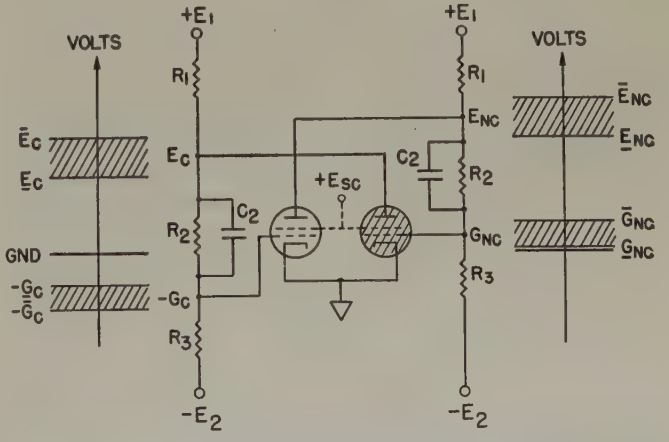

Figure 1. Grounded-cathode Eccles-Jordan flip-flop

Full text of paper 52-215, "Notes on the Design of Eccles-Jordan Flip-Flops," recommended by the AIEE Committee on Basic Sciencesand approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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The author wishes to acknowledge the incorporation of some basic concepts prevalent at the Institute for Advanced Study Computer Laboratory, where the work reported on here was begun. P. Levonian checked some of the lemmas experimentally, S. Ruhman verified the algebraic steps leading up to the lemmas, and the clerical staff of the Moore School assisted. The latter and greater part of the work described here was done in connection with Signal Corps Contract *DA-36-039-sc-14* for Electronic Computer Research and Development, placed by Signal Corps Engineering Laboratories, Department of the Army, Fort Monmouth, N. J.

least zero bias, (*c*) zero grid bias implies zero grid current.*

5. Only the grounded-cathode flip-flop is to be considered, and no inductors are to be used.

NOTATION

THE NOTATION USED in this article is illustrated in Figure 1. E_1 and E_2 refer to the positive and negative supply voltages, while E and G refer to plate voltage and grid voltage, respectively. Algebraic signs have been appended so that all symbols are positive quantities. Note the use of "max" and "min" to denote maximum and minimum; they will be applied to E_1, E_2, and all resistances with the same meaning. For example, R_1 (max) means $R_1(1+\rho)$. The subscripts C and NC refer to the C and NC divider networks connected to the conducting and nonconducting anodes. Finally, the transpose capacitance C_2 is assumed to be a variable parameter available to the designer, but the stray capacitances C_1 and C_3 in shunt with R_1 and R_3 are fixed by tube type and physical layout. In this regard it is worth mentioning that C_3 does not include Miller capacitance; this is certainly justifiable for the off tube, which is the only case treated in the following, but can be largely justified in any case.

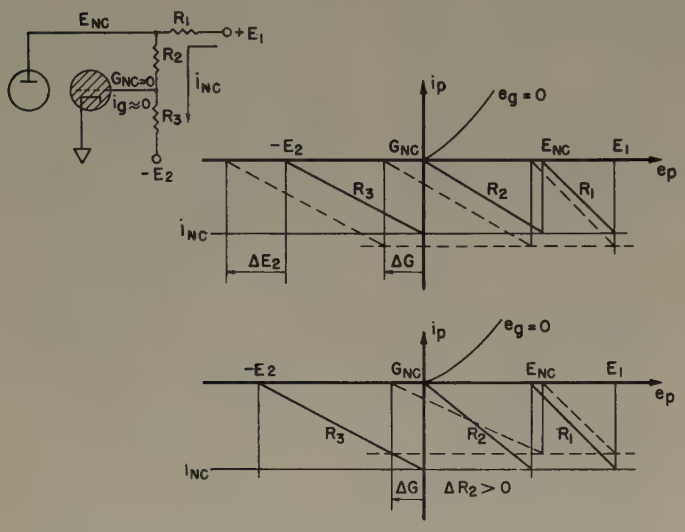

Figure 2. Influence of NC-divider parameters on stability

DERIVATION OF THE "WORST" CONFIGURATION

IT IS PROPOSED now to determine the "worst" possible configuration of the parameters, that is, that configuration most nearly approaching instability as defined in the foregoing. A graphical approach is to be employed, partly because it has proved to be simpler than the analytic method, but mainly because the graphical method is most illuminating and immediately applicable to design of more sophisticated flip-flops, of univibrators, and of all circuits using resistance divider networks.

Consider first the NC divider illustrated in Figure 2. Note in the upper graph the "minimum" plate characteristic for $e_g=0$, assumption 3. The divider current i_{NC} is drawn as if it were negative plate current, the reason to be given in the following. The solid lines labelled R_1, R_2, and R_3 are seen to be "load lines" for the respective resistors, that is, their slopes are the reciprocals of the resistances represented. The broken lines show the effect of more negative E_2 supply (larger E_2). Clearly, the resultant change in G tends toward flip-flop instability since the originally zero grid goes negative.

Similarly, the lower graph of Figure 2 shows that an increase in R_2 in the NC divider tends toward instability. By graphically studying the effect of varying each parameter, one at a time, its influence on stability is rapidly ascertained.

The C divider can be studied graphically in similar fashion, as shown in Figure 3. Here again the solid lines are load lines. Note in particular that the load line for R_1 fits properly onto this graph only because the divider current i_c has been treated as negative i_p. The graph shows that decreasing R_1 tends to instability because it tends to raise the grid voltage of the nonconducting tube. Actually, it is possible to derive more information from this graph by noting that the change ΔG is due to increased i_c which is in turn due to increase in E_C. It follows that decreasing R_1 will tend to instability whenever the plate characteristic has a positive finite slope at the point (E_C, i_p), a condition generally realized.

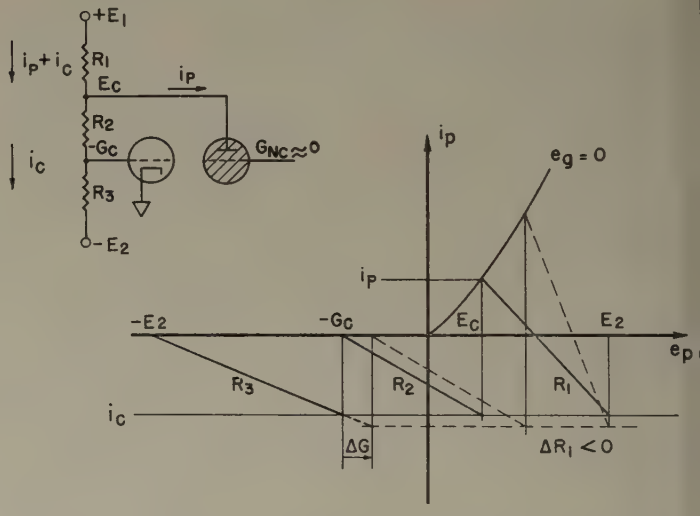

Figure 3. Influence of C-divider parameters on stability

The effect of variation of each parameter of the C divider can be studied graphically to yield information regarding tendency toward instability as well as associated conditions on the minimum plate characteristic. Although this is not to be carried through in this article, the results can be summarized as follows:

Lemma I: (*a*). For the NC divider, the most nearly unstable configuration is obtained with E_1 (min), R_1 (max), R_2 (max), R_3 (min), and E_2 (max);

(*b*). For the C divider, the most nearly unstable con-

*The grid current condition has been included only to simplify exposition. The graphical design procedure described in this article is readily modified to take account of grid current at zero grid bias.

figuration is obtained with E_1 (max), R_1 (min), R_2 (min), R_3 (max), and E_2 (min).*

One might object that Lemma I*a* and I*b* are inconsistent since E_1 and E_2 are the same for both dividers and hence cannot be both maximum and minimum simultaneously. However, the purpose is to design a flip-flop stable over long periods of time. Hence it is necessary to apply both parts of the lemma simultaneously in the initial design. Each part was independently derived for the same reason.

SOME DESIGN LEMMAS

LEMMA I can be applied to derive analytic expressions for the network resistances. Thus from Lemma I*a* it follows that:

$$i_{NC}=\frac{E_1\,(\min)}{R_1\,(\max)+R_2\,(\max)}=\frac{E_2\,(\max)}{R_3\,(\min)} \tag{1}$$

while from Lemma I*b* is obtained

$$i_c=\frac{E_c\,(\max)+G_c\,(\min)}{R_2\,(\min)}=\frac{E_2\,(\min)-G_2\,(\min)}{R_3\,(\max)} \tag{2}$$

$$i_p+i_c=\frac{E_1\,(\max)-E_c\,(\max)}{R_1\,(\min)} \tag{3}$$

These equations can be transferred by straightforward algebraic manipulation to

$$i_pR_1\,(\min)=E_1\,(\max)\delta^2+G \tag{4}$$

$$i_pR_2(\min)=\frac{E+G}{1-g}\left[\frac{1}{\beta^2-\dfrac{E+G}{(E_1\,(\max)-E)(1-g)}}-(1-g)\right] \tag{5}$$

$$i_pR_3\,(\max)=E_2\,(\min)\left[\frac{1}{\beta^2-\dfrac{E+G}{(E_1(\max)-E)(1-g)}}-(1-g)\right] \tag{6}$$

$$\beta^2=\frac{E_1\,(\max)}{E_1\,(\max)-E}\theta^2 \qquad \delta^2=1-\theta^2(1-g)$$

$$\theta=\frac{(1-\rho)(1-\sigma)}{(1+\rho)(1+\sigma)} \qquad g=\frac{G}{E_2(\min)}$$

$$E\equiv E_c\,(\max) \qquad G\equiv G_c\,(\min)$$

The following lemmas may be seen to follow almost immediately from equations 4, 5, and 6:

Lemma II: R_1, R_2, and R_3 are all inversely proportional to i_p; that is, all other things being equal, the resistances are minimized by choosing a tube with maximum perveance. (This lemma is modified slightly when $i_g\neq 0$ for $e_g=0$.)

Lemma III: R_1 is increased, R_2 and R_3 are decreased when a larger value of E_1 is chosen.

Lemma IV: If E_2 be chosen appreciably larger than G so that g is small, then R_1 and R_2 are almost independent of E_2. R_3 is approximately proportional to E_2.

Lemma IV*a*: A reasonable choice for E_2 would be $E_2\cong 10\,G_c(\min)$.

Lemma V: All three resistors increase as either resistance tolerance ρ increases or supply tolerance σ increases or both, for then θ and β decrease and δ increases.

* Study of the configurations of Lemma I will show that they do not result in extreme values of E; nevertheless, the notation E (max), E (min) will be used for this case.

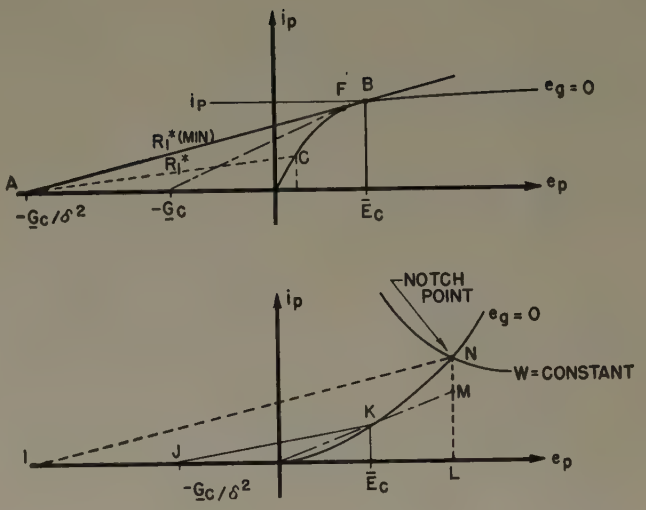

Figure 4. Determination of optimum E_C(max). Note: Superscript and subscript "bars" are used to denote maximum and minimum respectively

Since neither R_2 nor R_3 can be negative, it is necessary for the denominator of the first term inside the bracket of equations 5 and 6 to be positive. That is

$$\beta^2-\frac{E+G}{(E_1\,(\max)-E)(1-g)}>0 \tag{7}$$

and therefore:

Lemma VI: The minimum permissible value of E_1 is limited by the inequality $E_1\,(\max)>\dfrac{E+G}{1-g}\times\dfrac{1}{\theta^2}$.

Finally it is proposed to derive a criterion for choice of E_C (max). The criterion will be based on the assumption, believed to be approximately true, that flip-flop speed is inversely proportional to R_1, that is, that R_1 should be minimized. By Lemma III, this occurs when E_1 is chosen as small as possible. Applying Lemma VI to equation 4, one obtains:

$$i_pR_1\,(\min)>\frac{(E+G)\delta^2}{(1-g)\theta^2}+G=\frac{\delta^2}{1-\delta^2}\left(E+\frac{G}{\delta^2}\right) \tag{8}$$

It is helpful to introduce the resistance $R_1{}^*$ given by

$$i_pR_1{}^*=E+\frac{G}{\delta^2} \tag{9}$$

Thus, $R_1{}^*$ is a convenient measure of R_1.

Consider first a flip-flop designed around a pair of pentodes, so that G is fixed by the screen voltage. The upper graph of Figure 4 illustrates a construction for obtaining $R_1{}^*$ as defined by equation 9. The procedure consists of drawing a line such as AC from the point $\left(-\dfrac{G}{\delta^2},0\right)$ to intersect the minimum plate characteristic at C; if E be chosen to equal the plate voltage at C, the slope of the line AC is inversely proportional to $R_1{}^*$. Clearly, $R_1{}^*$ is minimized when the line is drawn tangent to the characteristic, as indicated by the solid line AB (labelled "$R_1{}^*$ (min)"). The point of tangency determines the optimum value of E. Since $0<\delta<1$, $R_1{}^*$ can never

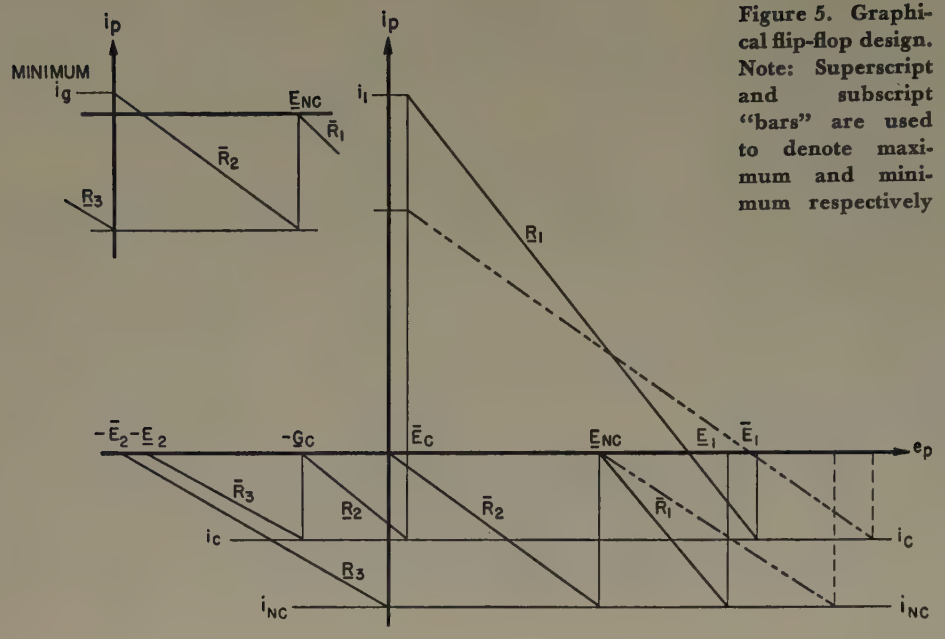

Figure 5. Graphical flip-flop design. Note: Superscript and subscript "bars" are used to denote maximum and minimum respectively

be decreased below the value corresponding to the dashed line passing through $(-G_C$ (min), 0) and tangent at F. Clearly, E should be chosen somewhere on the "knee" of the curve.

In the case of a triode flip-flop, the same reasoning leads to the result that E be chosen as large as possible. The upper limit is set by the rated anode power dissipation W. Hence, E should be chosen at the "notch point," N, at which the minimum plate characteristic intersects the "rated power" curve, W=constant, as shown in the lower graph of Figure 4. The broken line IN indicates the corresponding R_1* (min).

It should be recalled, however, that in the case of a triode, G is roughly proportional to E_1 which is in turn roughly proportional to E. Hence R_1* does not increase with decreasing E as rapidly as might otherwise be anticipated. The solid line JK shows the effect of reducing all voltages by a factor of two. By drawing a line from the origin through the new design point K to intersect LN at M and by applying the lemmas of similar triangles it can be shown that the new design point results in an increase in R_1* in the ratio of LN to LM. In practice the design point must be chosen well below the notch point because of other considerations, such as resistor power dissipation and magnitude of supply voltages. Consequently, this construction is a useful guide to the resultant increase in R_1.

The foregoing comments may be summarized as follows:

Lemma VII: (*a*). For a pentode flip-flop, E_C (max) should be chosen on the knee of the minimum plate characteristic.

(*b*). For a triode flip-flop, E_C (max) should be chosen as large as other considerations permit.

GRAPHICAL DESIGN PROCEDURE

THE ANALYTIC EXPRESSIONS for the network resistances given by equations 4, 5, and 6 of the previous section contain the following seven parameters, E_1, E_2, E, G, i_p, ρ, σ. The magnitudes of these parameters may be assigned arbitrarily by the designer, subject only to the condition on E_1 stated in Lemma VI. The assignment of values for ρ and σ is dependent upon knowledge of the characteristics of the resistors and of the power supplies to be used, while the selection of G and i_p depends upon a knowledge of the characteristics of existing vacuum tube types; clearly, "engineering judgment" must enter into the selection of values for these. At the same time, Lemmas IV, V, and VII serve as useful guides which restrict the ranges of ρ, σ, E_2, and E.

These remarks suggest that all seven parameters may be chosen in advance and that the analytic expressions of equations 4, 5, and 6 may be used directly for determining the values of R_1, R_2, and R_3. Where flip-flop application is not overly restricted by side conditions, this is probably true. However, it has been the author's experience in computer design that side conditions force the engineer to try many possible flip-flop designs. In this event the computation of the analytic expressions is time-consuming, and the graphical approach now to be described is much faster. Moreover, as we have seen, the graphical method immediately illustrates the influence of varying each parameter.

The design procedure is based directly upon Lemma I and the assumptions specified previously. The procedure is illustrated in Figure 5.

1. Set up i_p, e_p axes; the voltage scale is known, but the current scale is unknown initially.

2. Draw a line parallel to and below the e_p axis to represent i_c, the C-divider current. (It is convenient to make i_c=10 divisions.)

3. Locate $-E_2$ (min), $-G_C$ (min), E_C (max). Optimum choices for E_2 and E are based on lemmas IV*a* and VII; $-G_C$ (min) is the guaranteed grid cutoff bias. Draw load lines for R_2 (min) and R_3 (max).

4. Draw the load line for R_3 (min) in the NC divider. This line passes through $(-E_2(\max), 0)$ and $\left(-G_C(\min) - [E_2\ (\max) - E_2\ (\min)],\ i_c \frac{1+\rho}{1-\rho}\right)$. Produce this line to cut the current axis; the intersection is at i_{NC}, the current through all three NC-divider resistors.

5. Draw the load line for R_2 (max) in the NC divider; it passes through (0, 0) and $\left(E_c\ (\max) + G_c\ (\min),\ i_c \frac{1-\rho}{1+\rho}\right)$. Produce the line to i_{NC}; the corresponding voltage is E_{NC} (max).

6. Draw the load line for R_1 (max) in the NC divider; it passes through (E_{NC} (min), 0) and (E_1 (min), i_{NC}).

7. Draw the load line for R_1(min) in the C divider; it passes

through (E_1 (max), i_c) and $\left(E_{NC}\text{ (min)}+E_1\text{ (max)}-E_1\text{ (min)}, i_c-i_{NC}\frac{1+\rho}{1-\rho}\right)$. Produce to intersect E_C (max) at i_p. Then i_p is the minimum tube current at $e_p=E_C$ (max) for the most nearly unstable configuration, that is, it is the current obtained from the assumed minimum plate characteristic. Hence this determines the current scale for i_{NC} and i_c. Consequently all resistance values can now be obtained from this graph.

Since this procedure has been based on Lemma I, an analysis must show that any variation of one or more parameters within the allowed limits results in a stable flip-flop configuration.

No matter how the resistance values are calculated, it will in general happen that non-Radio-Television Manufacturers Association (RTMA) values will result. Lemmas II, III, and IV may be applied to rectify this situation. Thus, since i_p has been determined using "engineering judgment," it is quite reasonable to alter the preassumed value by some small percentage; this may be used to effect a small proportional rise or fall in all resistances. Again, a small percentage increase or decrease in E_1 may be used to vary the resistances in a nonproportional manner. Finally, R_3 may be adjusted with negligible effect on R_1 and R_2 by varying E_2. Where these lemmas cannot be used, as for example when E_1 and E_2 cannot be altered, the non-RTMA difficulty may be alleviated by designing with larger tolerances, ρ and σ, than engineering judgment demands.

The power of the graphical method is illustrated by two remarks. First, the broken lines on the right-hand side of Figure 5 instantly depict the influence of increased E_1 on the divider resistors. Since i_p is given and does not change, larger E_1 results in larger i_{NC} and i_c, and hence in smaller R_2 and R_3; at the same time, R_1 increases as is evident from inspection of the intersection of the two load lines for R_1 (min) with the voltage axis. Second, the graphical approach is easily extended to take account of grid current at zero grid volts; the method is indicated by the insert top left of Figure 5. The graphical method was used for a case when the analytic expressions were particularly complex; this was the design of a flip-flop with a guaranteed minimum grid current and also the ability to drive an *NE-17*, connected to the anode, with a prescribed minimum current. The saving in design time was deemed to be substantial.

GENERAL SWITCHING CONSIDERATIONS

There are at least two switching times of importance which must be distinguished. The first is the repetition rate, that is, the rate at which the flip-flop can switch repeatedly from one state to the other and back. Repetition rate is related to the settling time of the flip-flop, that is, the time required for the flip-flop to reach its new quiescent state.

The second switching time of importance is the switching speed, that is, the speed at which an initially quiescent flip-flop changes state. The switching speed is intimately related to the minimum duration of trigger pulse for successful switching. It will be shown that in general switching speed and repetition rate cannot be maximized simultaneously.

In both cases, the time of arrival at the new state must be defined *a priori*, say, through specification of output voltage.

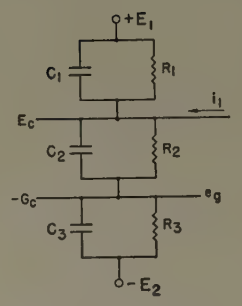

Figure 6. Initial conditions for rising grid voltage

Switching time is necessarily dependent on the kind of triggering used and on the amount of energy provided by the trigger pulse. For example, the ultimate in speed is achieved by a trigger which, by direct application to all appropriate points, instantaneously switches all voltages to their new values.

In practice, however, the trigger is applied to only one electrode for a time sufficient to insure change of state. It is proposed to consider the case when the conducting grid is instantaneously cut off. The problem is then reduced to determining the rate of rise of grid voltage of the initially nonconducting tube in response to a step of current, i_1, injected into the C divider between R_1 and R_2, as indicated in Figure 6. Therefore it can easily be shown that

$$e_g(t)=G_{NC}-(G_{NC}+G_C)[(1+b)\epsilon^{-\alpha t}-b\epsilon^{-\gamma t}] \tag{10}$$

where

$$b=b(\tau_2)=\frac{\alpha(1-\gamma\tau_2)}{(\gamma-\alpha)}$$

$$\gamma,\alpha=\frac{1}{2R_i\tau_j\tau_k}\left[(R_i+R_j)\tau_k \pm S\right]$$

$$S^2=[(R_i+R_j)\tau_k]^2-4(R_i)(R_i\tau_j\tau_k)$$

$$\tau_k=R_kC_k$$

$$R_i=R_1+R_2+R_3$$

$$R_i\tau_j\tau_k=R_1\tau_2\tau_3+R_2\tau_3\tau_1+R_3\tau_1\tau_2$$

$$(R_i+R_j)\tau_k=(R_1+R_2)\tau_3+(R_2+R_3)\tau_1+(R_3+R_1)\tau_2$$

Also it can be shown that $S^2\geqslant 0$ and therefore $\gamma\geqslant\alpha$. The equality signs hold if and only if $\tau_1=\tau_2=\tau_3$.

In what follows, it is assumed that τ_2 is the only explicit variable available to the designer and that all other terms are parameters adjustable within the limits set by stability requirements. An inspection of equation 10 shows that the transient term consists of two exponential terms, of which the first requires longer to decay since $\alpha<\gamma$. Moreover, the variation of γ and α with τ_2 can be obtained immediately from the expressions of equation 10. Thus it can be shown

Lemma VIII: (*a*). $\gamma\geqslant H$; $\gamma\to H$ as $\tau_2\to\infty$, but limit $\gamma\geqslant H$;

(*b*). $\alpha\leqslant H$; limit $\alpha=0$ as $\tau_2\to\infty$.

where

$$H=\frac{(R_1+R_2+R_3)(R_1\tau_3+R_3\tau_1)}{(R_1\tau_3+R_3\tau_1)^2+R_1R_2\tau_3^2+R_2R_3\tau_1^2}$$

When $\tau_1=\tau_3$, then $H=\frac{1}{\tau_1}$ and the equality signs in Lemma VIII are obeyed. Moreover, note that the largest value of α is less than the smallest value of γ, regardless of the value of τ_2, for any specific design.

The coefficient b has been defined in equation 10; in particular, it can be seen that

$$b(0)=\frac{\alpha}{\gamma-\alpha}>0 \qquad (11)$$

It follows that both coefficients are positive for $\tau_2=0$. It can be shown that:

Lemma IX: As τ_2 increases, both coefficients decrease through zero and become negative. In particular, $b=0$ when τ_2 equals the smaller of τ_1 and τ_3; $(1+b)$ equals zero when τ_2 equals the larger of τ_1 and τ_3.

Since α can never exceed γ, minimum settling time can only be achieved by eliminating the term exponential $(-\alpha t)$, that is, by making $(1+b)=0$. Consequently

Lemma X: To achieve minimum settling time, τ_2 should be chosen equal to the larger of τ_1 and τ_3. Settling time is then dependent only upon γ.

Two observations are worthy of note. First, this value of γ does not differ too markedly from $1/\tau_1$. It follows that the magnitude of τ_1 constitutes a good first approximation to flip-flop speed. This circumstance was utilized in the previous section in choosing optimum E_c (max) on the basis of minimum R_1. Second, when τ_2 equals the larger of τ_1 and τ_3, the equation for γ simplifies to

$$\gamma=\frac{R_1+R_2+R_3}{(R_1+R_2)\tau_3+R_3\tau_1};\ \tau_1=\tau_2>\tau_3$$
$$\gamma=\frac{R_1+R_2+R_3}{R_1\tau_3+(R_2+R_3)\tau_1};\ \tau_1<\tau_2=\tau_3 \qquad (12)$$

As pointed out, the foregoing criterion was chosen to satisfy minimum settling time. It is common experience, however, that repetition rate can be improved by introducing a small amount of overshoot at the expense of settling time. It is not difficult to show the following:

Lemma XI: Overshoot occurs if and only if τ_2 is greater than both τ_1 and τ_3.

It has been found experimentally for one flip-flop design that maximum repetition rate was obtained when τ_2 exceeded the larger of τ_1 and τ_3 by about 10 per cent.

To obtain maximum switching speed requires that the grid voltage e_g rise at its maximum rate. By differentiating e_g with respect to time t in equation 10, it can be shown that:

Lemma XII: For maximum switching speed, τ_2 should be so chosen that

$$\tau_2>>\frac{R_2\tau_3\tau_1}{R_1\tau_3+R_3\tau_1} \quad \text{or} \quad C_2>>\frac{C_1C_3}{C_1+C_3}$$

In words, C_2 should be chosen much larger than the capacitance of the series connection of C_1 and C_3.

The influence of τ_2 on switching speed is illustrated by the curves of Figure 7, which show e_g versus time for various values of τ_2. Note that these curves are a pictorial verification of Lemmas X, XI, and XII.

The use of large τ_2 to obtain maximum switching speed implies the existence of appreciable overshoot. In the case of the rising grid, this is of no consequence since the grid is clamped at cathode voltage. On the other hand, it is the same network which is involved in fall time considerations when the flip-flop returns to its original state. Consequently there will be a similar overshoot in the case of the falling grid, probably of increased magnitude because of the initial grid clamping. The overshoot reduces the ultimate repetition rate since it causes the grid, when re-

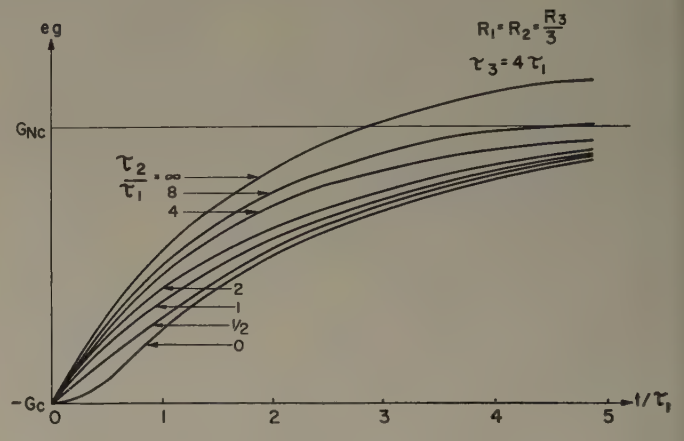

Figure 7. The influence of τ_2 on switching time

triggered soon after having been triggered, to start out from a voltage below $-G_C$ and hence to take longer to rise. Thus it appears qualitatively that the two switching times, repetition rate and switching speed, cannot be optimized simultaneously.

CONCLUSION

This article has been concerned with the design of Eccles-Jordan flip-flops. After restricting the scope of the discussion to a particular design and to specific assumptions, analytic design expressions were obtained and a number of lemmas developed with regard to optimizing parameters while guaranteeing stability within stated parameter tolerances. Finally, a general graphical design procedure was developed.

The use of a transpose capacitor to improve switching times was discussed and a number of lemmas developed to serve as a guide not only in the choice of a transpose capacitor but also in choice of other parameters (particularly R_1 and R_3) within the stability limits previously obtained.

The article makes no claim to completeness, but is meant only to serve as a collection of rules to guide the design of flip-flops.

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Wave Filter Characteristics by a Direct Method

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IN FILTER DESIGN the determination of expected attenuation may be accomplished by the use of the basic formula for the propagation constant of a ladder-type half-section, $P=\alpha+j\beta=\sinh^{-1}\sqrt{ZY}^{/\phi}$, but this necessitates long and tedious calculation. Graphical methods often have been used but the lengthy calculation of $\sqrt{ZY}^{/\phi}$ usually has remained even with dissipation neglected.

Seven widely used ladder filter sections are shown in Figure 1, together with the symbols used to designate them in this article. The attenuations of all seven can be read from the chart shown in outline in Figure 2. It can be used directly for sections *2A*, *3A*, and *3B* entering the chart with n, the number of bandwidths to the adjacent cutoff frequency, and p, the bandwidth divided by geometric mean frequency. The upper branches of the attenuation curve are shown as solid lines, and the lower branches dotted. A logarithmic scale is selected to magnify the important region near the passband.

The sections *2B*, *3C*, and *3D* which have a frequency scale inverse to that of the *2A*, *3A*, and *3B* sections can be read from the same chart by modifying the abscissas for Figure 2. The *4A* attenuations are the sum of those for the *3A* and *3C* types. The *2A* and *2B* attenuations appear on the $p=\infty$ curve with $n=(f-f_2)/f_2$ for *2A* and $n=(f_1-f)/f$ for *2B*.

Formulas for the abscissas with which to enter Figure 2 and also the attenuations obtained for a specific filter with

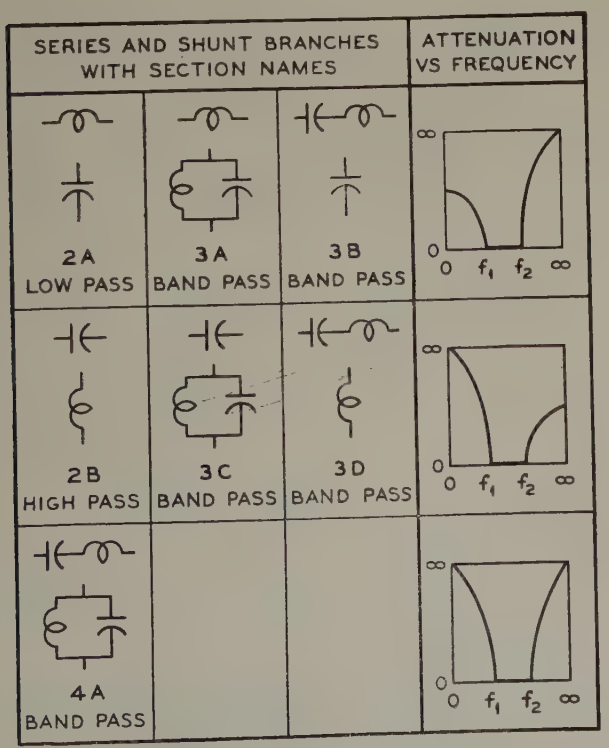

Figure 1. Ladder filter sections

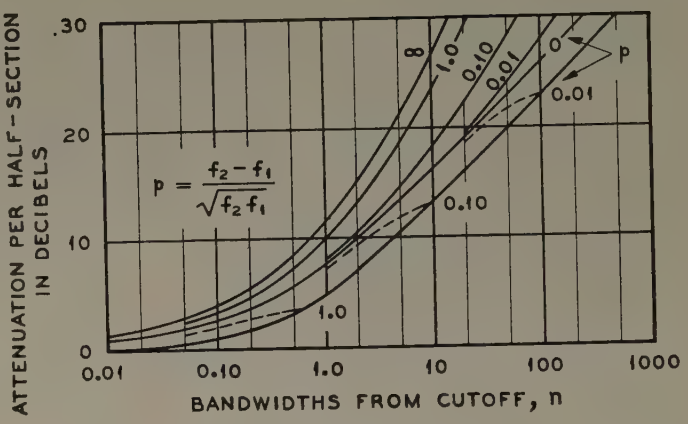

Figure 2. Attenuation chart

$f_1=950$, $f_2=1{,}050$, $w=f_2-f_1=100$ and $p\cong 0.1$ are:

	3A and 3B	3C and 3D	4A
$f<f_1$ . . . abcissa . . . $n=\frac{f_1-f}{w}$	5	$\frac{f_2}{f}n$	11.7
$f=450$ . . . db	12	19	31
$f>f_2$ . . . abcissa . . . $n=\frac{f-f_2}{w}$	5	$\frac{f_1}{f}n$	3.07
$f=1{,}550$ . . . db	14.5	10.5	25

The formula for the upper curves of Figure 2 is

$$\alpha_{3AB}=\cosh^{-1}\left[\sqrt{(1+n)-(1-n^2)\frac{w}{2f_2}}\Big/\sqrt{1-\frac{w}{2f_2}}\right] \quad (1)$$

For the dotted curves of Figure 2

$$\alpha_{3AB}=\sinh^{-1}\left[\sqrt{n-n^2\frac{w}{2f_1}}\Big/\sqrt{1+\frac{w}{2f_1}}\right] \quad (2)$$

and above the passband.

The modified abscissas given for *3C* and *3D* sections can be avoided by constructing a similar chart to be entered with n directly. Below the passband

$$\alpha_{3CD}=\cosh^{-1}\left[\sqrt{(1+n)+(1-n^{-2})\frac{w}{2f_1}}\Big/\left(1-\frac{nw}{f_1}\right)\sqrt{1+\frac{w}{2f_1}}\right] \quad (3)$$

and above the passband

$$\alpha_{3CD}=\sinh^{-1}\left[\left(1-\frac{w}{f_2}\right)\sqrt{n+n^2\frac{w}{2f_2}}\Big/\left(1+\frac{nw}{f_2}\right)\sqrt{1-\frac{w}{2f_2}}\right] \quad (4)$$

Since $p=(f_2-f_1)\sqrt{f_1f_2}$

$$\frac{w}{f_2}=\frac{p^2}{2}\left[\sqrt{1+\left(\frac{2}{p}\right)^2}-1\right] \quad \text{and} \quad \frac{w}{f_1}=\frac{p^2}{2}\left[\sqrt{1+\left(\frac{2}{p}\right)^2}+1\right] \quad (5)$$

Digest of paper **52-85**, "Wave Filter Characteristics by a Direct Method," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Industrial Applications of Magnetic Amplifiers

R. W. MOORE

Numerous outstanding advantages of "Magamps" are presented which help make possible more reliable, faster, simpler, and inherently more stable regulating systems. Several industrial applications exemplifying these characteristics are discussed.

A REGULATING system is an integral part of many drives for industrial applications. Magnetic amplifiers or "Magamps"* have been applied as flexible and powerful elements in these regulating systems. In its simplest form a Magamp is a variable reactance between a source of alternating voltage and a load. A relatively small amount of d-c power, which varies the reactance by saturating the magnetic core, can control the large power to the load. However, the art has progressed far beyond the implications of this simplified description, particularly when the magnetic amplifier is applied as a component in a regulating system. Many magnetic amplifier circuits have been devised, each having advantages for a particular type of application. A recent bibliography lists nearly 900 patents and articles covering saturable core devices and magnetic amplifiers. Although saturable reactors have been used as amplifiers for 35 years, several more recent developments have made possible the fast, flexible, and powerful control device of today. First was the self-saturating circuit which raised the ratio of power gain to response time by a factor of 100. Second was the development of magnetic materials which gave high gain with high output. Third was the development of selenium and other dry-type rectifiers which function to improve gain, stability, and reliability.

The self-saturating magnetic amplifier is illustrated in its simplest form by Figure 1*A*. The alternating current or load winding of the reactor is connected in series with a rectifier, a load, and an a-c supply. The reactor also has a d-c control winding. For this idealized half-wave circuit, it would be necessary to use a high impedance in series with the control winding to minimize the dissipation of a-c power resulting from the alternating voltage induced in the control winding. The rectifier in the load circuit prevents reversal of current during the negative, opposite to rectifier, half cycle of voltage. During this half cycle the flux density of the core is determined by the value of the current in the d-c control winding. During the positive half cycle of voltage, the reactor absorbs voltage until the core is saturated, at which time the reactance has become a minimum and a pulse of current flows through the load. By adjustment of the control current minimum or maximum reactance, and therefore maximum or minimum load current, is obtained. The applied voltage and load-current output for one value of control winding current is shown in Figure 1*B*.

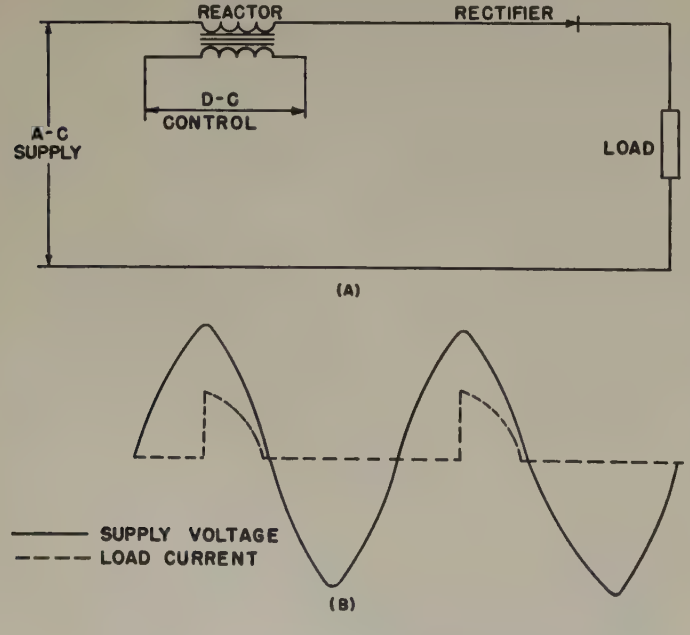

Figure 1

A—Half-wave self-saturating magnetic amplifier
B—Load current wave shape

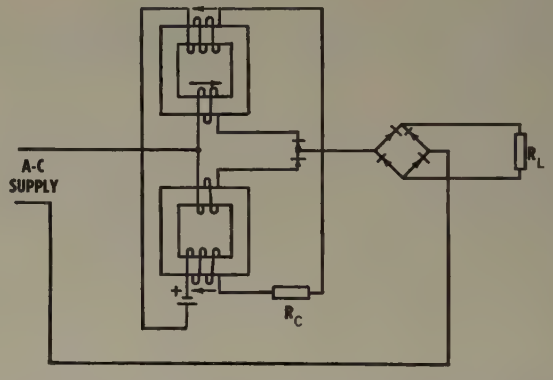

Figure 2. Full-wave parallel self-saturating Magamp

This simplified circuit permits current flow only during positive half cycles. To obtain load current during each half cycle, two of the half-cycle units, as shown in Figure 1*A*, can be connected in parallel: one for operation during the positive half cycle, and the other for operation during the negative half cycle. This parallel self-saturating circuit is illustrated in Figure 2. A bridge rectifier has been in-

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* Westinghouse trade-mark.

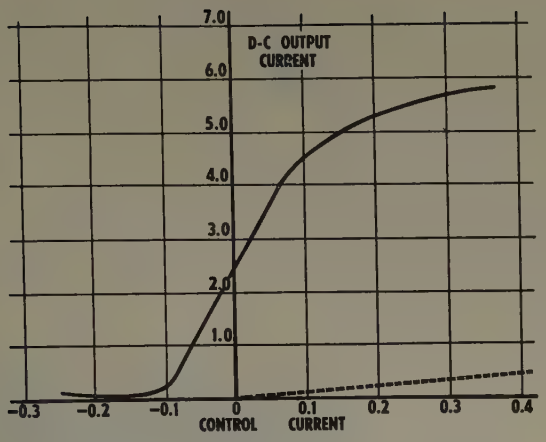

Figure 3. Magamp control characteristic

cluded in the load circuit in order to obtain d-c load current. This circuit has the advantage that the control windings can be connected such that the induced voltages cancel, thus permitting operation with low-impedance control circuits. There have been many circuits devised to accomplish these same functions and several different core configurations can be used. However, the basic principles of operation are the same as described for the simplified half-wave circuit. In general, practical consideration of a particular application dictates the choice of circuit. The parallel self-saturating circuit, as shown in Figure 2, has proved to be suitable for most industrial applications.

A typical control characteristic is illustrated in Figure 3. Although this particular curve is applicable to a magnetic amplifier with "C" cores the general shape of the curve is typical for all types. This curve illustrates that a single-unit magnetic amplifier having rectifiers to provide d-c output will provide only one polarity of output. However, a variety of circuits have been devised to provide reversing polarity with d-c output. Two separate magnetic amplifiers, each delivering output of the proper polarity, can be used. This becomes essentially a 2-channel amplifier. In other circuits, the load is supplied by a single magnetic amplifier for one polarity and a separate source of d-c potential is used for the other polarity.

Self-saturating magnetic amplifiers have been applied in many regulating systems for industrial applications. They have been used as voltage regulators on d-c or a-c generators up to the largest central station sizes. They have been used to obtain current limit on adjustable-voltage drives, to control the firing of ignitron rectifiers, as speed and position regulators, and as speed controls for cranes and hoists.

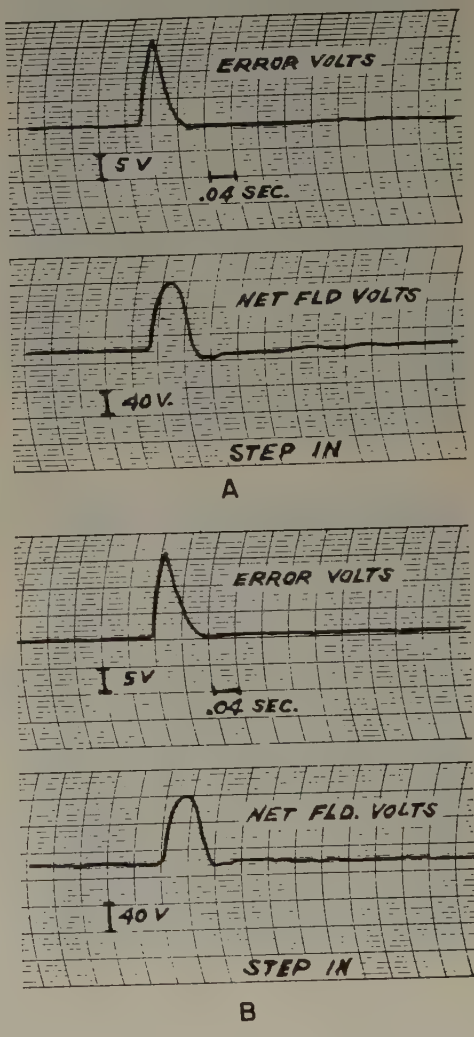

Figure 5. Response of a 400-cycle Magamp section

A—Response with motor at full field
B—Response with motor at weak field

The Magamp control for the individual generator drive of one stand of a tandem cold reduction mill is shown schematically in Figure 4. A tandem cold mill may consist of three to five main stands. The drive motor for each stand is supplied from an individual adjustable-voltage generator. In order to maintain proper synchronization

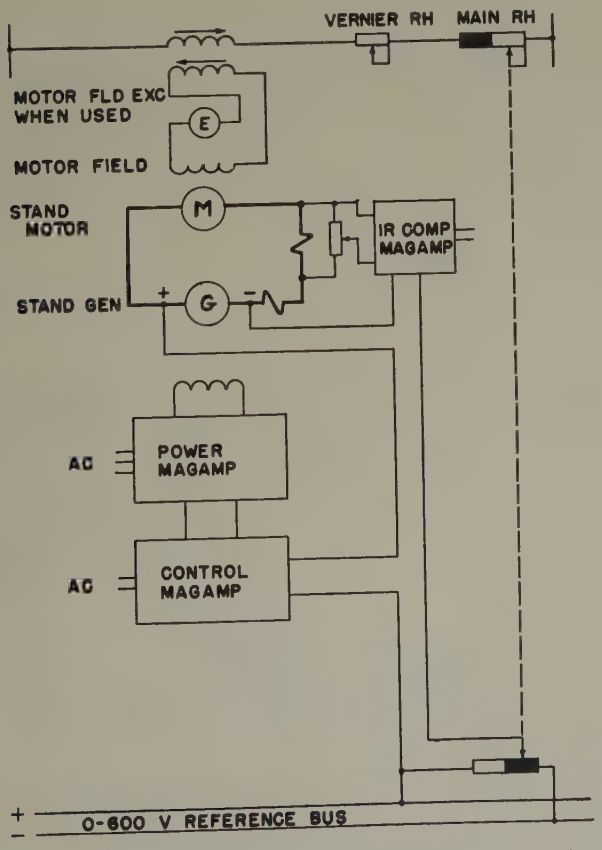

Figure 4. Individual generator tandem cold mill schematic

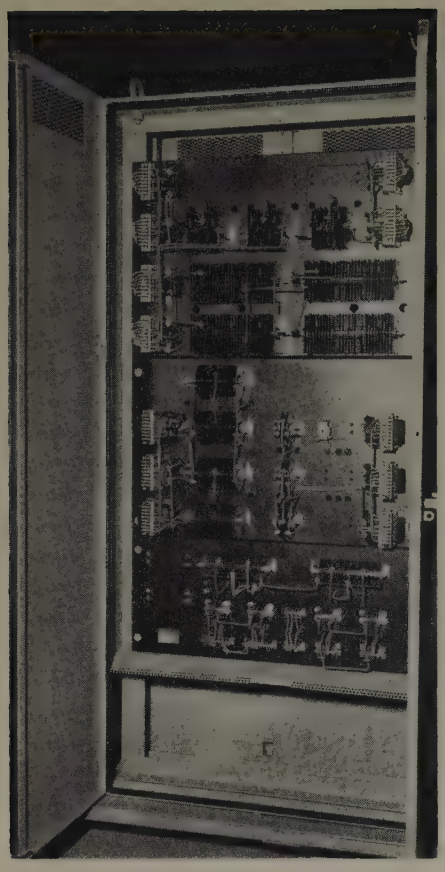

Figure 6. Output stage of a 400-cycle Magamp

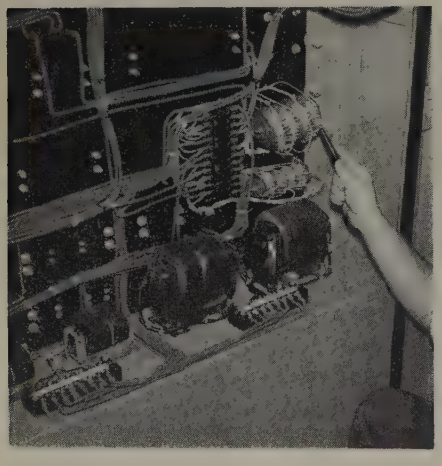

Figure 7. Control stage and voltage drop compensation 400-cycle Magamps

between stands, each stand drive is matched to a common control reference bus and the mill is accelerated and decelerated by raising and lowering the reference bus voltage. Figure 4 shows that the individual stand generator voltage is matched against that of the reference bus and the difference is applied to the control Magamp. If the generator voltage differs from the reference bus voltage, the control Magamp changes its output. In turn the output of the power Magamp and the generator voltage is changed to correct the difference. Voltage drop compensation is obtained by means of a small separate Magamp, the output of which is proportional to motor armature current. This output voltage is connected in series with the generator voltage and the reference bus in order to obtain increased generator voltage with load. By using sufficient voltage-drop compensation, the system of Figure 4 is essentially a counterelectromotive force speed regulator.

Approximately a 7 to 1 reduction in minimum Magamp time delay can be obtained by using 400 instead of 60 cycles. Therefore, the Magamps for this system were designed for 400 cycles to minimize the damping requirement, simplify adjustments, and obtain the ultimate in response and performance.

The transient response of this system is shown in Figure 5.

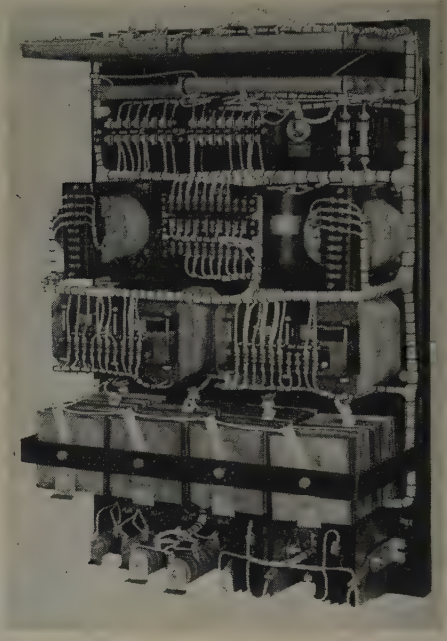

Figure 8. A 60-cycle Magamp panel

An instantaneous change in reference voltage was obtained by suddenly switching a battery into the circuit. The error volts or difference between generator and reference voltage was recorded and the chart shows that the generator response is completed in less than 0.1 second with the motor at either full or weak field. Measurements of the net generator field excitation voltage showed that this

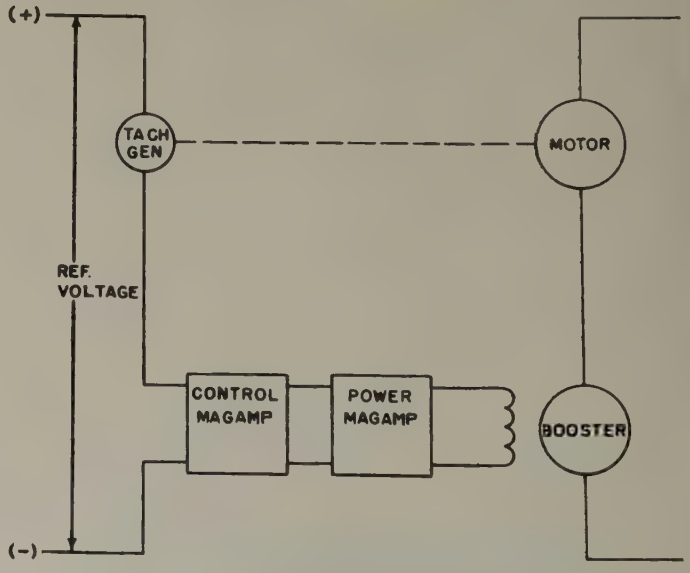

Figure 9. Speed follow-up system

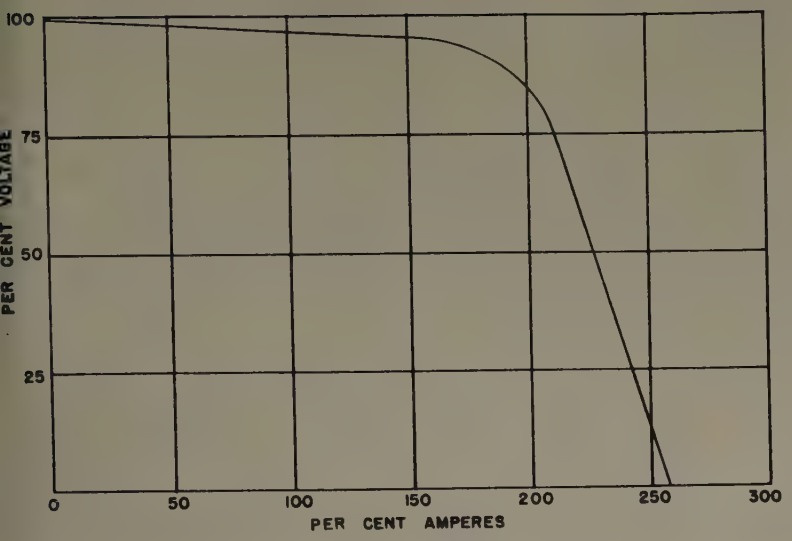

Figure 10. Static volt-ampere characteristic of current limit Magamp section

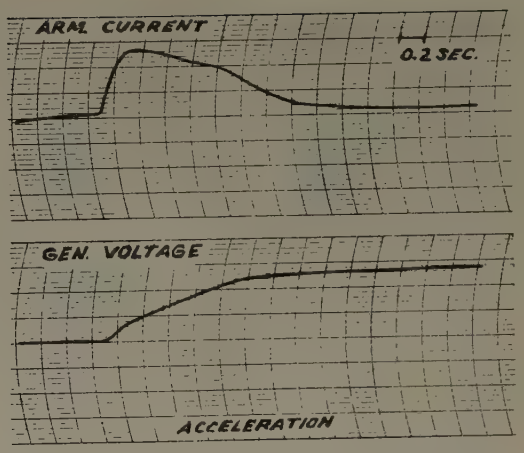

Figure 11. Transient response of current limit

voltage reached a peak of 465 per cent of the operating value in order to force this rapid change of generator voltage.

The output stage of the 400-cycle Magamp which supplied power directly to the field of the 3,600-kw generator is shown in Figure 6. A view of the rear of this cabinet, Figure 7, shows the control stage Magamp and the voltage drop compensation Magamp.

For most industrial applications, 60-cycle Magamps have proved entirely adequate and are less costly than 400 cycles. A 60-cycle Magamp panel is shown in Figure 8. This panel contains not only the control and power Magamps but also damping devices and adjusting resistors. A schematic illustrating how this Magamp control has been applied in a speed follow-up system for a mill processing line is shown in Figure 9.

Many applications of adjustable-voltage drive require current limit in order to obtain maximum accelerating rates with safe operating conditions. This can be obtained very successfully with Magamps. The static volt-ampere characteristic of this type of drive is illustrated in Figure 10. The slope of the volt-ampere character in the current limit region can be controlled by adjusting the gain of the current limit Magamp. The transient current limit action is illustrated by the oscillograph chart of Figure 11. This chart was obtained starting with the drive at standstill and throwing the master switch to the "Full On" position. Generator voltage and armature current have been recorded. The chart shows that the current is limited and maintained at this limit over the major portion of the acceleration. Motor speed will follow applied voltage as determined by the mechanical time constant.

In the paper, steel, and textile industries materials are reeled many times as they are processed from raw materials to finished product. It is generally required to maintain constant material tension as the coil of materials builds up on a core-type reel. Figure 12 illustrates schematically such a reel drive and the tension control. The reel drive motor is supplied from a voltage proportional strip speed and a Magamp current regulator comparing reel motor current to a reference operates on the motor field to reduce the motor speed and increase the motor torque with increasing coil build-up.

The number and variety of industrial applications of Magamps are increasing at an accelerating rate because they have several outstanding advantages:

1. Long life corresponding to coils and dry-type rectifiers.
2. Require no periodic maintenance; there are no tubes to replace and there are no bearings, brushes, or commutators to cause trouble.
3. The units can be panel mounted, consequently

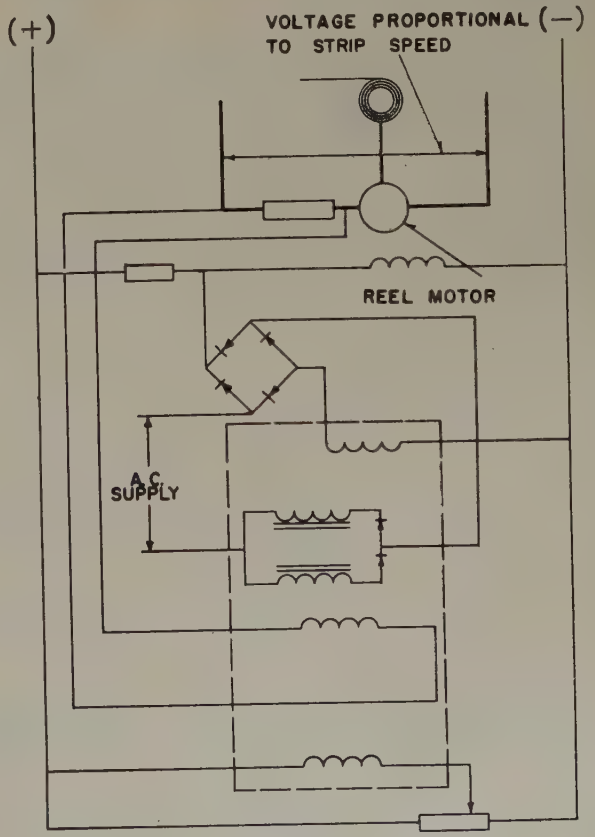

Figure 12. Reel drive Magamp control

simplifying the installation and reducing expenditures.

4. Provide simple isolation of signals since the coupling is inductive.

5. Are more resistant to shock.

6. Smaller damping devices are required as compared to rotating amplifiers.

A few typical industrial applications have been described which illustrate these characteristics. Usually, as a result of these characteristics a more reliable, faster, simpler, and more inherently stable regulating system is obtained.

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Ferroelectric Storage Elements for Digital Computers and Switching Systems

J. R. ANDERSON

These ferroelectric storage devices, although still comparatively new, show great promise. They can store up to 2,500 bits of information per square inch in a surface only a few thousandths of an inch thick with pulses less than a microsecond long.

THE GROWING NEED for improved types of data storage systems in both the digital computer and telephone switching fields has led to the investigation of ferroelectric materials as memory devices. Among the objectives in developing these devices have been low power consumption while storing or reading out information, memory access times of 1 microsecond or less, small size per bit of memory, simplified low cost construction, and high reliability. This article presents an explanation of the operation of a basic storage circuit employing a ferroelectric material, requirements for suitable materials, descriptions of several types of circuits employing ferroelectrics, and experimental data from operating circuits.

FERROELECTRIC MATERIALS FOR MEMORY CIRCUITS

FERROELECTRIC MATERIALS are dielectrics in which electric dipoles occur spontaneously and align themselves parallel by mutual interaction. Therefore, the dielectric induction versus applied electric field intensity curves for ferroelectric materials show hysteresis loops similar to the *B-H* curves for ferromagnetic materials. Thus the designation ferroelectric material signifies the dielectric analogue of a ferromagnetic material rather than a material containing iron.

A number of dielectric materials such as barium titanate, rochelle salt, potassium niobate, and potassium dihydrogen phosphate have been found in recent years to have ferroelectric properties. At the present time barium titanate ($BaTiO_3$) appears to be the most practical of these materials for use in memory circuits. It remains ferroelectric over a temperature range from below 0 to about 120 degrees centigrade and it will polarize with lower electric field strengths than are required for any other known ferroelectric material except rochelle salt. Rochelle salt has the disadvantage of being ferroelectric only from about −15 to about +20 degrees centigrade.

Especially prepared single crystals of barium titanate 0.004 to 0.010 inch thick and having an area up to about 0.1 square inch have been used for the experimental memory circuits described here. These crystals and methods of obtaining characteristics suitable for memory circuits were developed by J. P. Remeika of the Bell Telephone Laboratories. Silver paste electrodes about 0.025 inch in diameter are placed on opposite sides of the crystals in one or more positions to form individual memory cells. A typical crystal with two sets of 0.020-inch diameter electrodes attached is shown in Figure 1.

As will be shown later, substantially rectangular hysteresis loops and low coercive forces are desirable in ferroelectric materials to be used in memory circuits. Barium titanate crystals and ceramics which have been prepared for transducer and capacitor application in general are not satisfactory for memory circuits because of their high coercive forces and nonrectangular hysteresis loops.

Revised text of paper 52-309, "Ferroelectric Materials as Storage Elements for Digital Computers and Switching Systems," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Fall General Meeting, New Orleans, La., October 13–17, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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On Figure 2 are shown 60- and 6,000-cycle hysteresis loops for one type of barium titanate crystal which is suitable for memory circuits. Hysteresis loops of the type shown are observed by applying voltages proportional to electric field strength and polarization to the horizontal and vertical plates respectively of a cathode-ray tube when a 60- or 6,000-cycle electric field is applied across the ferroelectric material. Circuits for accomplishing this are described in references 1 and 2. The 60-cycle loop illustrated in Figure 2*A* has an extremely high ratio, greater than 50 to 1, between the slope at the sides and the slope at the bottom and top, and shows that 100 volts is required to saturate the crystal. Other crystals of this type are now available which saturate with only 25 volts peak applied voltage for 0.005-inch thicknesses. Figure 2*B* illustrates the manner in which the slope of the loop and the remanent polarization decrease at higher frequencies.

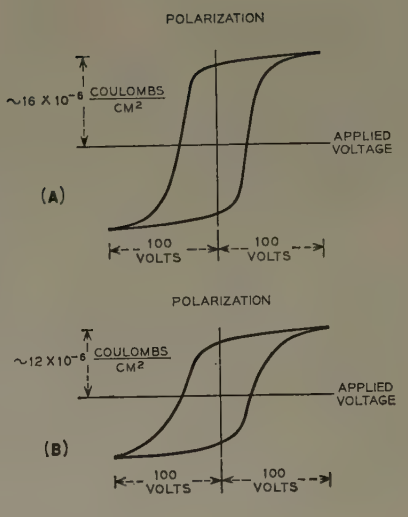

Figure 2. Hysteresis loops traced from an oscilloscope display for a barium titanate crystal 0.0045 inch thick: A—60-cycle loop. B—6,000-cycle loop

It has been found that another type of barium titanate crystal requiring about 200 volts to drive 0.0035-inch-thick crystals to saturation also has a stable low-voltage hysteresis loop in the 10-volt range. Hysteresis loops for a material of this type are illustrated in Figure 3.

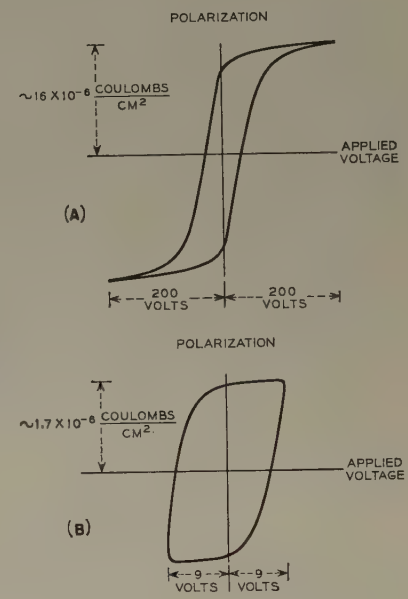

Figure 3. Hysteresis loops traced from an oscilloscope display for a barium titanate crystal 0.0035 inch thick: A—60-cycle loop for 200 volts peak applied voltage. B—60-cycle loop for 9 volts peak applied voltage

While single-frequency hysteresis loops such as those illustrated are useful in predicting the performance of memory circuit materials, they do not give complete information because square pulses containing a wide band of frequencies are applied to the materials in operating circuits.

THE BASIC FERROELECTRIC MEMORY CIRCUIT

THE BASIC CIRCUIT consists of a minute capacitor containing a ferroelectric material as the dielectric in series with an output capacitor which is shunted by a rectifier or resistor as shown in Figure 4. The rectifier, which may be of the germanium diode type, is used only when it is desirable to prevent storage pulses from appearing across the output of the memory circuit.

The operation of this circuit may be explained by referring to the dynamic ferroelectric hysteresis loop of Figure 5. The shape of this loop approximates the observed 60-cycle loop of Figure 2*A*. The ordinates on Figure 5 are P, the polarization of the crystal, and the abscissas are V, the applied voltage, which is equal to the applied electric field strength, E, times the crystal thickness, t. For any segment of the loop, the capacitance of the crystal is the ratio of the change in polarization per unit volume to the change in applied field. If A is the plate area and $V=Et$, then $C_s=A/t\ dP/dE=AdP/dV$ where C_s is the crystal capacitance. It is observed from the figure that this ratio is large along the steep parts of the segments B to C and A to D, and small over the segments A to C and B to D. In its normal state of polarization, when a binary "0" is stored, the ferroelectric material will be in state A. If a positive read out pulse is applied, the loop is traversed from A to C and then back to A upon removal of the pulse. The slope of the loop along this part indicates a low capacitance. Since the capacitance of the fixed output capacitor in the basic circuit is high compared to this capacitance, the peak output voltage will be low under this condition, which is the same as reading out a binary "0". When a binary "1" is stored in the material by applying a negative pulse, the loop is traversed

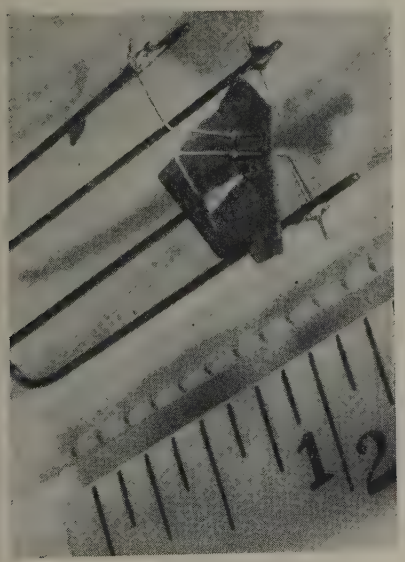

Figure 1. Barium titanate crystal containing two independent memory cells. The top spots or plates for each cell with attached lead wires can be seen on the visible face of the crystal

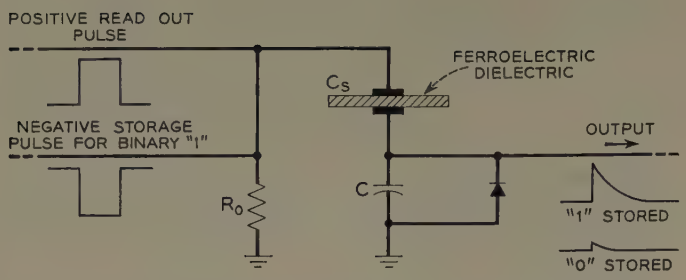

Figure 4. Basic ferroelectric memory circuit schematic diagram

from A to D and then back to B leaving the material in state B upon removal of the pulse. If a positive read-out pulse is now applied the material will change from state B to B' during the initial rise of the pulse. B' is the point at which the product of the voltage across the ferroelectric times its capacitance becomes equal to the product of the voltage across the output capacitor times its capacitance. The capacitance at B' is quite high as indicated by the steep slope of the hysteresis loop at this point and most of the voltage of the read out pulse appears across the fixed output capacitor. As the output capacitor discharges through the back resistance of the diode, the voltage across the ferroelectric increases until point C, saturation, is reached. When the read-out pulse is removed, the loop is traversed from point C back to A and the ferroelectric is again left in its normal state.

The polarities of the storage, read-out, and output pulses can be reversed from those shown in Figure 4 if the direction of the diode is also reversed.

CALCULATIONS OF OUTPUT CAPACITANCE FOR THE BASIC MEMORY CIRCUIT

The ratio for the output voltage V_o'' when reading out a stored "1" to the read-out voltage V_I is expressed by:

$$\frac{V_o''}{V_I}=\frac{C_s''}{C_s''+C} \tag{1}$$

where C_s'' is the high capacitance state of the ferroelectric, and C is the fixed output capacitor.

The ratio of output voltage V_o' when reading out a stored "0" to the read out voltage is expressed by:

$$\frac{V_o'}{V_I}=\frac{C_s'}{C_s'+C} \tag{2}$$

Now let $C_s''=XC_s'$, where C_s' is the low-capacitance state of the ferroelectric. It then follows from equations 1 and 2 that:

$$C=C_s''\frac{(R-1)}{(X-R)} \tag{3}$$

where R is the ratio of output voltage when reading out a stored "1" to that when reading out a stored "0".

When the shape of the dynamic hysteresis loop is known it is possible to calculate the best value for the fixed output capacitor C by using equation 1. A value of V_o''/V_I is chosen which will allow the ferroelectric hysteresis loop to be initially traversed up to point B', Figure 5, on its steep section. Then after determining X from the hysteresis loop, equation 3 can be used to determine the ratio R to predict the performance of the circuit. It has been found that when C_s'' and C_s' values obtained from 60-cycle hysteresis loops are used for calculations with equations 1, 2, and 3, good agreement is obtained with observed results using storage and read out pulses which are 5 milliseconds or longer. For pulses in the microsecond range, C_s'' and C_s' values must be obtained from hysteresis loops made at much higher frequencies. In the latter case it usually is easier to determine the optimum value of the fixed capacitor C experimentally with an operating circuit.

The back resistance R_B of the diode, or a resistor replacing the diode, shown in Figure 4 must be low enough in value to allow the essentially complete discharge of capacitor C and charge of C_s during the length of a pulse so that the voltage across the ferroelectric always will rise to the value of the storage and read-out pulses.

PERFORMANCE OF THE BASIC MEMORY CIRCUIT

BASIC MEMORY CIRCUITS, employing material of the type for which the hysteresis loop is illustrated in Figure 2*A*, have been constructed which operated satisfactorily on ±30-volt storage and read-out pulses which are 5 milliseconds long. The output voltage when reading out a stored binary "1" is 25 volts, and the output for reading out a stored binary "0" is only about 0.6 volt, when using a 0.01-microfarad output capacitor.

Circuits operating on the low-voltage loops such as are illustrated in Figure 3*B* have been used with storage and read-out pulses 9 volts in amplitude and 5 milliseconds long, and give output pulses of about 3 volts and 0.3 volt, respectively, for reading out a binary "1" and a binary "0" with a fixed output capacitor of 0.001 microfarad. With 30-volt storage pulses 0.1 microsecond long and 10-volt read-out pulses 3/4 microsecond long, the output pulses are 3 volts after storing a binary "1" and about 1 volt after storing a binary "0" with a 100-micromicrofarad output capacitor. However, the ratio of the areas under these respective pulses is about 10 to 1.

As the information stored in the ferroelectric material depends upon internal polarization and not on surface charge, the memory of the material will last for several days even with the electrodes short-circuited during this time. When operating on the low-voltage loop as illustrated in Figure 3*B*, it has been found that the output voltage when reading a binary "1" left stored for 16 hours is about one-half that observed when reading out a binary

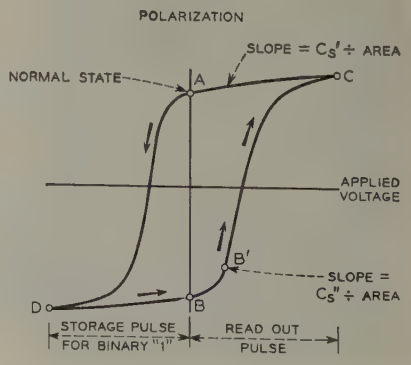

Figure 5. Dynamic ferroelectric hysteresis loop

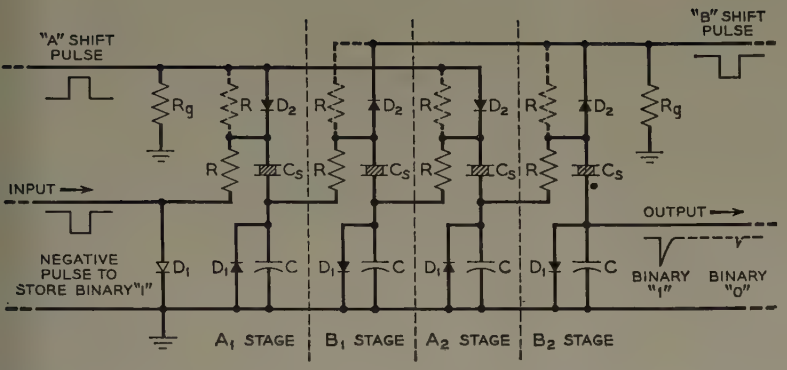

Figure 6. Ferroelectric memory circuit with serial input and serial output. C_s is capacitor with ferroelectric dielectric

"1" stored for only a few minutes. However, when operating with saturation loops as shown in Figure 2, stored binary information lasts several days without change.

It has been found that several independent sets of electrodes can be placed on the same crystal of barium titanate without appreciable interference between adjacent memory cells. For example, the crystal shown in Figure 1 has two separate memory cells with a separation of only 0.005 inch between edges of electrodes on the same surface. Tests on this unit showed that information could be stored and read out continually from either one of the cells without appreciably affecting the information stored in the other cell.

ENERGY, POWER, AND CIRCUIT CONSIDERATIONS FOR THE BASIC MEMORY

The energy required for storing a binary digit "1" in the basic ferroelectric memory circuit, assuming a diode across the output capacitor, is determined by the area of the dynamic hysteresis loop and the electrode area. The energy required for reading out a binary digit "1" is determined by the same factors and must also include the energy required to charge the output capacitor. No energy is required to hold a digit in storage and the energy required for reading out a binary "0" will be very small compared to that required for reading out a binary "1".

When operating with storage and read-out pulses of the order of 5 milliseconds long, it has been found that the dynamic or operating hysteresis loop approaches the general shape of the 60-cycle hysteresis loop. On this basis it has been calculated that the energy for storing a binary digit "1," with a 9-volt pulse using a material having a hysteresis loop such as is shown in Figure 3*B* with 0.020-inch diameter electrodes, is about 7.4×10^{-8} joules. If binary digits are stored at the rate of 100 per second, the average power consumed will be 7.4 microwatts. The average power required for reading out a stored binary "1" at the same rate is 7.8 microwatts.

The energy required when operating with pulses in the microsecond range is less than that required for relatively long pulses because the area of the dynamic hysteresis loop decreases at higher frequencies. The energy consumption for storing a binary digit "1" with 30-volt pulses is calculated to be about 2.05×10^{-8} joules which would give an average power consumption of 20.5 milliwatts when storing at a rate of 1,000,000 per second. The average power for reading out a binary digit "1" at the same rate with a 100-micromicrofarad output capacitor and 10-volt read-out pulses will be about 2.8 milliwatts.

The basic ferroelectric memory circuit of Figure 4 has been extended for use in a number of circuits which might find applications in the digital computer or telephone switching field. In Figures 6 to 10, inclusive, are presented five of the most important types. The polarities of storage and read-out pulses as shown in these circuits may be reversed if the polarities of the diodes shown are also reversed.

PARALLEL INPUT AND OUTPUT STORAGE CIRCUIT

A number of storage circuits like the one shown in Figure 4 can be operated in parallel from a single read-out pulse generator. The electrodes for all of the storage cells may be on a single crystal because each pair of electrodes will act independently of all others to polarize a small crystal segment. Since each storage cell in the parallel array will have its own input and output leads, the information to be stored will arrive on parallel input leads. The stored information is simultaneously read out of all storage cells by a single read-out pulse. Diodes are used between each storage cell and the read-out pulse generator to prevent coupling of the cells through the pulse generator.

SERIAL INPUT AND OUTPUT STORAGE CIRCUITS

A circuit for storing and reading out binary digits in serial form is shown in Figure 6. While the circuit, as shown, provides places for storing only two binary digits, additional digits can be stored by adding one *A* stage and one *B* stage for each additional digit to be stored. Negative pulses are used to store binary "1's" and no input pulses to store "0's."

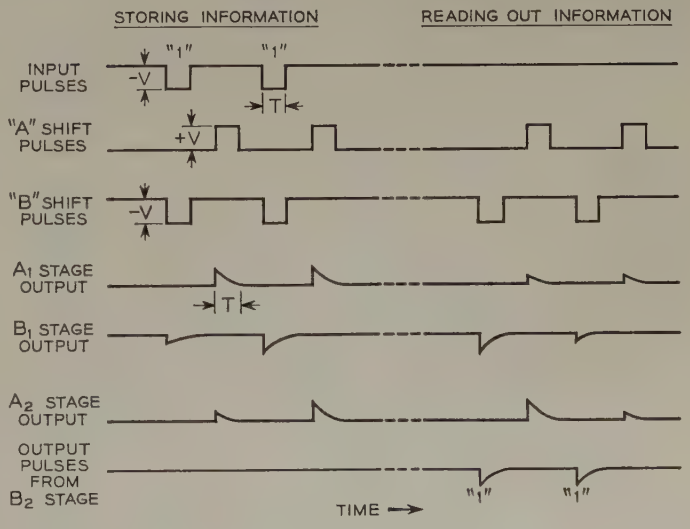

Figure 7. Voltage pulse progression in serial memory circuit of Figure 6 when storing and reading out the binary number "11"

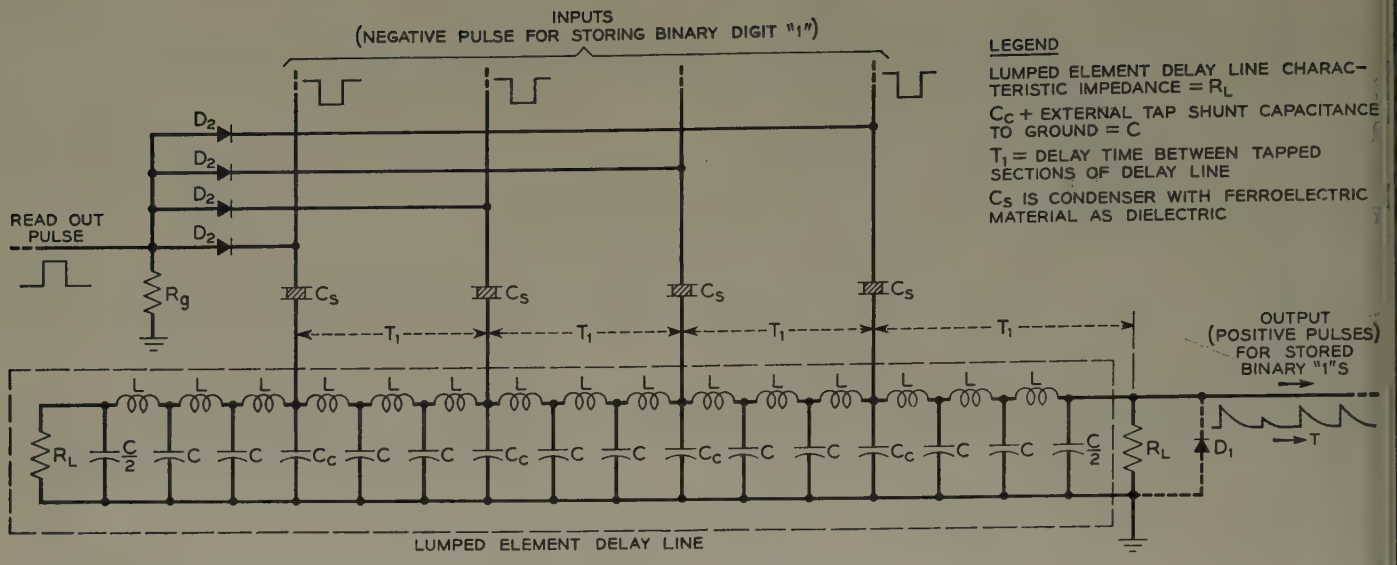

Figure 8. Ferroelectric memory circuit with delay line output

The first digit to arrive is stored in the A_1 stage, then is transferred to the B_1 stage by the A shift pulse before the next input pulse arrives. The second digit is stored in the A_1 stage at the same time that the first digit is transferred from stage B_1 to stage A_2 by the B shift pulse. Both digits are then transferred by the A shift pulse to the B_1 and B_2 stages respectively. The information then remains stored until B and A shift pulses are again applied at which time the first digit appears at the output and the second digit transfers to stage A_2. The second digit then transfers to stage B_2 and then to the output. The time relations of the various pulses used to store and read out the binary number "11" are shown in Figure 7.

Pulses are prevented from passing backward from the B stages to A stages when B shift pulses are applied by making the resistance of R large compared to the forward resistance of diode D_1. The D_2 diodes are used to prevent coupling between the two A stages and between the two B stages. The back resistance of these diodes should be large compared to the series combination of R and the back resistance of the D_1 diode. The output capacitor C of each stage includes the effective shunt capacitance of the following stages. The value of R_g should be equal to or greater than R to allow at least one-half the output voltage of each stage to be applied to the next stage. Calculations for the value of capacitor C are the same as for the output capacitor of the basic memory circuit.

The circuit of Figure 6 can be modified to eliminate one-half of the diodes required by replacing the D_2 diodes with resistances R as shown dotted in on the circuit diagram. The value of R_g must then be low compared to R to prevent coupling between the outputs of the two A stages or between the two B stages. It is also necessary in this modification to double the magnitude of the input and A and B shift pulses because of the voltage division which occurs when each diode D_2 is replaced by a resistance R.

Serial-type circuits comprising two to four cells have been constructed and operated with 5-millisecond pulses. It has been found that the output voltage of these circuits even when loaded down on the output with a shunt resistance and capacitance equal to that for adding following stages is as high as the output from the A_1 or first input stage. Thus any number of stages may be added in tandem.

DELAY LINE OUTPUT CIRCUIT

Figure 8 shows a circuit in which binary digits arriving on parallel leads are stored in ferroelectric memories and then pulsed into tapped points on a delay line. The stored information appears in serial form at the output of the delay line. The parallel memory circuits operate in the same manner as the basic circuit of Figure 4, capacitor C of Figure 4 being replaced by the effective shunt capacitance C_1 of the delay line at the tap points. A single diode D_1 can be shunted across the output of the delay line when it is desirable to keep input storage pulses from appearing on the output. The voltage pulses on the input and output when a binary number "1011" is stored and read out are also illustrated in Figure 8.

While only four storage cells are shown, more cells can be added in parallel as long as additional sections of delay line are added to provide delay T_1 between each tap point. The total number of delay line sections which can be added is limited by the attenuation of pulses passing down the delay line.

The circuit of Figure 8 has been tested using a Western Electric *D-172597* delay line and single barium titanate crystals tapped in at various points along the line. This delay line has a characteristic impedance of 415 ohms, shunt capacitance C, see Figure 8, of 75 micromicrofarads, a cutoff frequency of about 8 megacycles, and a total delay of about 5 microseconds. The crystals used had very high saturation voltages so that 1/2-microsecond pulses 115 volts in amplitude were required to store and read out information. Output voltages of 27 and 4.4 volts, respectively, were observed when reading out a stored binary "1" and "0" with the crystal connected to a tap point 1.7 microseconds from the output. With a crystal tapped into a point 3.4 microseconds from the end of the line, the output voltages for reading out stored binary "1's" and "0's" were 23 and 4.0 volts respectively.

STORAGE CIRCUIT WITH RELAY OUTPUT

The circuit of Figure 9 illustrates a ferroelectric storage circuit which operates a polar relay when a binary digit "1" is read out or leaves the relay in an unoperated condition when a binary digit "0" is read out. The output of this circuit consists of open or closed relay contacts which may be used to light a lamp, operate other relays, or perform some other function. Information may be stored in the ferroelectric when the relay is either in its operated or unoperated condition because diode D_1 allows the ferroelectric to be polarized by an input pulse without passing current to the relay. The relay operates when a read-out pulse is applied and a binary "1" has been stored previously in the ferroelectric because the ferroelectric presents a capacitance in this state which is sufficient to cause a large current pulse to flow through the relay. When the ferroelectric is polarized in the same direction as the read-out pulse, a binary "0" is stored, application of the read-out pulse will initiate only a small current pulse through the relay due to the very low capacitance of the ferroelectric in this state. Thus, the relay cannot operate when reading out a binary "0".

Due to its "locking" polar characteristics, the relay remains operated after receiving a large current pulse and can be reset only by passing a reverse current through it with the reset switch shown in Figure 9. The capacitance C shown in the figure may be added when the area of electrodes on the ferroelectric is too small to provide sufficient capacitance to operate the relay. The capacitance C must be smaller than that required to operate the relay so that there will be no operation when reading out a stored binary "0" from the ferroelectric.

The circuit shown in Figure 9 has been used to operate a Western Electric type-*276D* relay with 45-volt read out and storage pulses. A shunt capacitor C of 0.1 microfarad was used with the ferroelectric because the electrode area of the latter was only about 0.009 square inch. This circuit has always operated successfully even when reading out a binary "1" which had been left stored in the ferroelectric for a period of one week.

2-DIMENSIONAL STORAGE CIRCUIT

The 2-dimensional storage array provides a means for compacting a large number of storage cells into a small area and eliminates the requirement for individual output capacitors and diodes or resistances for each cell.

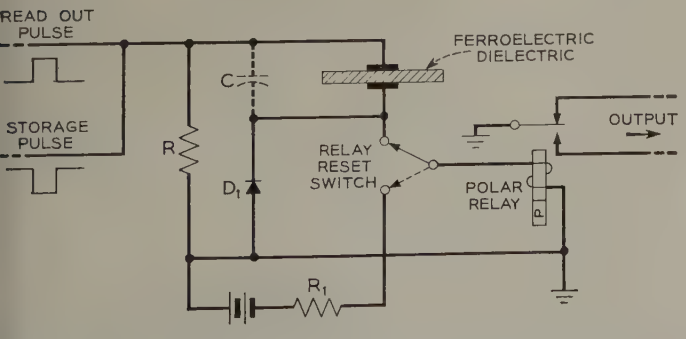

Figure 9. Ferroelectric memory circuit with relay output

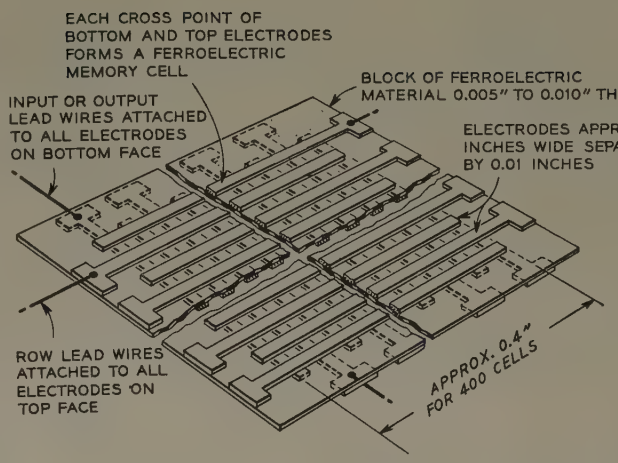

Figure 10. Physical embodiment of a 2-dimensional ferroelectric storage array for 400 binary digits

The physical embodiment of this system consists of a large single crystal having a set of parallel-line electrodes on one face perpendicular to a set of parallel-line electrodes attached to the other face as shown in Figure 10. Each crosspoint of the top and bottom electrodes forms a separate memory cell and information may be stored independently in and read out of any of these cells or of any row of cells. A binary digit "1" may be stored in any cell of the array by applying one-half the voltage required to polarize the ferroelectric to one top electrode and an equal but opposite polarity voltage to one bottom electrode. The cell in which the digit is stored will be that formed by the crosspoint of these electrodes. Thus, the full polarizing voltage will appear across that cell, but only one-half the polarizing voltage will appear across all other cells in the array. The information is read out of any individual cell by applying a full polarizing voltage of opposite polarity to that used for storing a binary digit "1," across the cell and an output capacitor shunted by a resistance as in the basic memory circuit. By storing information in all cells of one row simultaneously, and reading out information from all cells in another row simultaneously, it is possible to arrange the output circuit so the capacitance of all other memory cells in each column acts as the fixed output capacitor for that column. With this 2-dimensional circuit as many as 2,500 bits might be stored on a 1-inch-square crystal of the order of 0.005 inch thick.

This type of circuit requires a ferroelectric material which will not change its original state of polarization whenever positive or negative voltage pulses one-half the amplitude of the normal polarizing pulses are applied across the material. Such a material has become available recently and preliminary tests with this material containing two cells in the same row and in the same column have indicated that it might be possible to extend the 2-dimensional type of operation to a large array as shown in Figure 10.

CONCLUSIONS

Even though ferroelectric storage devices are in their early developmental stages and present access prob-

lems in a large array, they show considerable promise as a new method for storing digital information in computers or switching systems. These devices provide a means for storing up to 2,500 bits of information per square inch in a surface only a few thousandths of an inch thick with pulses less than a microsecond long. In addition they offer the possibility of operation from low-voltage, 10-volt or less, circuits such as transistors, consume no power during the storage period, are adaptable to a wide variety of circuit combinations, and provide storage for long periods of time without regeneration.

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2. Piezoelectricity (book), **W. G. Cady.** McGraw-Hill Book Company, Inc., New York, N. Y., 1946. Pages 559–60.

Standard Basic Impulse Insulation Levels: 450 to 1,050 Kv Inclusive

A JOINT COMMITTEE REPORT

The AIEE-EEI-NEMA Joint Committee on Co-ordination of Insulation, at its meeting in New York, N. Y., May 8 and 9, 1950, adopted the values of impulse voltages given in Table I as Standard Basic Impulse Insulation Levels and prepared Table II to illustrate the allocation of these levels.

The work of this Joint Committee is a review and re-examination of the Standard Basic Impulse Insulation Levels (BILs) presented to the industry in January 1941.[1]

The previous array of impulse insulation levels were established on the premise of nongrounded system operation. The present revision provides for both nongrounded and effectively grounded system operation.

The following quotations from the original report apply equally well to this report:

"Basic impulse insulation levels are reference levels expressed in impulse crest voltage with a standard wave not longer than 1.5x40 microsecond wave."

"The general principle of insulation co-ordination requires a reasonable margin between the voltage level held by the protective device (the protectable level) and the various basic levels themselves to insure that adequate protection is provided. The values in Table I (of the 1941 report) have been set up on this basis. It is felt that the values so set up are on a sound basis and that they are most likely to stand without change for a long time. It is the opinion of the Committee, therefore, that the various technical committees working on standards can adopt the values given in this report for standardization purposes, and it is further believed that the use of these values will result in ultimate over-all benefit to the industry."

This report covers BILs applicable in nominal system voltages in the transmission range. Future work will cover system voltages in the subtransmission and distribution voltage ranges.

The allocation of basic impulse insulation levels to equipment for use on systems in the transmission range of voltages can be covered in almost all cases illustrated in Table II tabulations.

Table I. Standard Basic Impulse Insulation Levels

450	750	900
550	825	1,050
650		

Values are in crest kv for a 1.5x40 microsecond full wave.

Table II. Allocation of Basic Impulse Insulation Levels

Nominal System Voltage	Basic Impulse Insulation Levels for Equipment Protected* by Lightning Arresters in Close Relationship Thereto		
	"100 Per Cent" Lightning Arresters	"80 Per Cent" Lightning Arresters	"75 Per Cent" Lightning Arresters**
Kv Line-to-Line Col. I	(BIL-Kv) Col. II	(BIL-Kv) Col. III	(BIL-Kv) Col. IV
(92)†	450		
115	550	450	
138	650	550	
161	750	650	
(196)†	900	750	
230	1,050	900	825

* When equipment is located outside the effectively protected zone established by lightning arresters, higher levels should be considered.

** Lightning arresters of this rating should be selected only on the basis of a detailed study of system operating conditions.

† Not preferred nominal system voltages.

REFERENCE

1. Standard Basic Impulse Levels, **Joint AIEE–Edison Electric Institute–National Electrical Manufacturers Association Report.** AIEE *Transactions*, volume 60, 1941, page 1448; EEI Publication Number *H-8*, NEMA Publication Number *109* (New York, N. Y.), January 1941.

Full text of paper 52–232 recommended by the AIEE Committee on Standards and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952. Not scheduled for publication in AIEE *Transactions*.

This is a report of the AIEE–Edison Electric Institute (EEI)–National Electrical Manufacturers Association (NEMA) Joint Committee on Co-ordination of Insulation. Chairman of the AIEE group is J. H. Foote, of the EEI group Philip Sporn, and of the NEMA group H. H. Rudd, succeeded in July 1950 by G. W. Clothier. The report was prepared by J. E. Clem for NEMA, J. H. Foote for AIEE, and R. E. Pierce for EEI.

Present Worth

P. H. JEYNES
MEMBER AIEE

THE OBJECTIVE OF economic comparisons is to estimate in advance the financial effect of adopting one particular plan of action instead of some alternative. One of the major factors in such studies is the return on investment, representing the annual rental paid for money.

The fact that money does command an annual rental is obvious. If the rate of return is 6 per cent, an initial investment of $100 earns $6 by the end of the first year, making a total of $106 available for investment throughout the second year, and so forth. This is the familiar law of accumulations at compound interest:

The amount of $1 placed at interest, compounded annually at i per cent for n years equals $(1+i/100)^n$.

The present-worth factor is simply the reciprocal of the foregoing compounding factor. That is, if P dollars (=present worth) invested today at i per cent compounded annually amounts to $1 in n years: $P(1+i/100)^n=1$, and $P=1/(1+i/100)^n$.

It is inescapable that if we provide for a return we must also discount all future costs; the two operations are simply alternative ways of expressing the same phenomenon. Note particularly that the phrase "present worth" does not imply an appraisal of property in terms of today's reproduction cost; it means specifically the arithmetical result of discounting future payments for interim return on investment.

THE BASIC COST COMPARISON

The simplest, most readily comprehended, universally applicable, and direct approach in economic problems is a comparison of future revenue requirements, meaning the annual gross receipts necessary to recover all annual costs including return on investment. A variety of practical problems illustrate the general method, and the importance of discounting future costs. Applied to the familiar "straight-line" depreciation convention, three conclusions of interest are demonstrable: 1. "return plus average interest," sometimes proposed as the appropriate "straight-line" depreciation arithmetic, is only a rough approximation; 2. the particular method used by the company to account for book depreciation is of no moment in economic comparisons; and 3. the present worth of future annual costs of return plus depreciation is equal exactly to first cost. This last observation provides a useful test for correctness of depreciation arithmetic.

ECONOMIC CRITERIA

The process of "capitalizing" annual costs, though popular and convenient, very often is done incorrectly. To illustrate, consider the familiar problem of determining economic conductor size. Let C=capital cost of larger conductors, c=annual carrying-charge percentage for conductors, G=capital cost of generating stations, g=annual carrying-charge percentage for generating stations, and e=incremental energy cost per year.

The break-even equation, in terms of annual costs, is $Cc=Gg+e$. In terms of "capitalized" costs it is the apparently simpler form $C=G+E$, where E is the capitalized energy cost, obtained by dividing e by the appropriate percentage—obtained how? It is not c, nor g; nor is it the rate of return, as so many conclude. The appropriate percentage, $=(Cc-Gg)/(C-G)$, can be determined only by examining the expression for annual costs.

It is sometimes assumed that the most economic plan is the alternative yielding minimum costs per kilovolt-ampere, but this is not always the case for reasons which become apparent when the comparison is properly made on the annual-cost basis. The safest, simplest, most direct and rigorous procedure is to tabulate annual costs over the appropriate period and compare their present worth.

Strictly speaking, the term of the comparison is from the date of installation to eternity; but practically, it is ordinarily determined by one of two considerations: 1. The date after which annual costs will be identical whichever plan is selected; or 2. The date which is so far in the future (say 50 or 60 years) that annual cost differences thereafter have insignificant present worth. At 6-per-cent return, the present worth of $100 per year 50 years from now is only $5.43 per year; the present worth of $100 per year 100 years from now is 29 cents per year.

The effect of increasing price levels on comparative costs is usually of small importance except in some problems of economic replacement when the equipment involved has a very long life, the decision to replace or not must be made at an early age, and rapid price rises are predicted.

Appropriate methods for estimating the effect of any stipulated rate of increase in prices are quite specific. In general, the effect of price rises is to reduce the repair expenditure that is justified as an alternative to replacement.

Having prepared estimates of the investment costs and expenses associated with various alternative plans, the relative economics of the several proposals is desirably expressed as a comparison of the present worth of their respective annual revenue requirements. That same present-worth arithmetic is indispensable in several parts of the estimating process, some of which are described in this article.

Digest of paper 51-360, "Present Worth, or the Time Cost of Money, as a Factor in the Economic Comparison of Alternative Facilities," recommended by the AIEE Committee on System Engineering and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Published in AIEE *Transactions*, volume 70, part II, 1951, pages 1956–62.

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Two-Phase A-C Servo Motor Operation

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MANY PRESENT-DAY servo systems employ the 2-phase induction motor as the electromechanical energy conversion member. Common practice is to supply one phase from a suitable constant-voltage source while the pertinent control information is carried in the form of the voltage magnitude variation impressed on the second or control winding. This voltage is maintained displaced at 90 degrees from the main winding voltage.

Some time ago a proposal was made that a servo system employing such a motor be designed in which the control information is carried in the form of the varying phase angle of a constant magnitude control voltage. For a good servo system this phase angle between the two constant magnitude phase voltages must be made directly proportional to the error.

In the conventional servo system both the signal and the noise are of an amplitude nature and consequently, if the noise is of an appreciable amount, the operation of the system may be affected adversely. If, however, the information is transmitted in the form of a varying angle of constant voltage, the noise will have little or no effect even in cases where the control signal is small.

For the preliminary analysis of such a control system, an experimental steady-state study was made to determine speed-torque curves of typical 2-phase motors when subjected to the two kinds of control. The tests were made on low-wattage motors built by Diehl Manufacturing Company. A general expression for torque-speed curves is

$$T=\frac{\delta T}{\delta n}n+\frac{\delta T}{\delta \psi}\psi \qquad (1)$$

where T=torque, n=motor speed, ψ=control quantity.

Curves of torque plotted as a function of control quantity are shown in Figure 1. These results show the main difference between the torque function of motors operated with the two kinds of control. The curve for the voltage-controlled motor approaches a fairly straight line (B) giving a constant for the value of $\delta T/\delta\psi$. Linear differential equations with constant coefficients thus can be written for the voltage-controlled case. The phase-controlled motor on the other hand has a characteristic that approaches a sine function of the control, curve (A). The value of $\delta T/\delta\psi$ for the phase-controlled case is a sine function rather than a constant. This gives an equation that is nonlinear and as such has at present no formal solution.

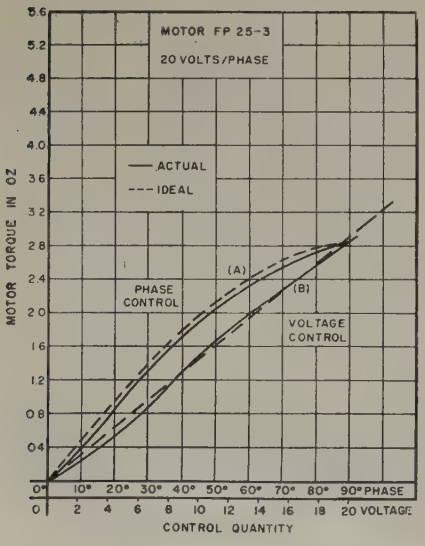

Figure 1. Curves of torque plotted as a function of control quantity

The motor torque equations are

$$T=-K\omega_o+K_A\epsilon \qquad (2)$$

for voltage control, and

$$T=-K\omega_o+K_B\sin\epsilon \qquad (3)$$

for phase control; where $-K$ is the slope of the speed-torque curve below 2,000 rpm, ω_o is the output speed, K_A is the value of $\delta T/\delta\psi$ for $\omega_o=0$, K_B is the maximum blocked motor torque, and ϵ is the control quantity in proper units. The experimental results are verified analytically in several ways. The most direct means is by the method of symmetrical components. The motor time constant can be computed directly from the speed-torque curve.

To use the motor properly with phase control in a servo system requires that the error (difference between input and output of closed loop system) be transformed into a directly proportional amplified phase shift, of the form $\sin K_1(\theta_{\text{input}}-\theta_{\text{output}})$. For a simple viscous servo system the equation is

$$T_s\frac{d\omega_1}{dt}+\omega_o=K_s\sin K_1(\theta_{\text{input}}-\theta_{\text{output}})$$

where T_s is the over-all system time constant, and K_s is the system velocity constant.

One disadvantage of a system employing phase shift control is that some means must be employed to cause the motor to exert maximum torque (90 degrees phase shift) even when the quantity $K_1(\theta_{\text{input}}-\theta_{\text{output}})$ is greater than 90 degrees. Another disadvantage is that full voltage is applied to both motor windings at all times which means, on the average, more heating than when employing voltage control.

However, in referring to Figure 1 it is evident that for the phase control case the motor exerts somewhat more torque per unit control quantity than for the voltage control case.

Digest of paper 51-366, "Two-Phase A-C Servo Motor Operation for Varying Phase Angle of the Control Winding Applied Voltage," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Published in AIEE *Transactions*, volume 70, part II, 1951, pages 1987–93.

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Production Impulse Testing of Distribution Transformers

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Impulse testing, when used as a quality control tool in the manufacturing of distribution transformers, functions as an invisible inspector and acts as a final check on manufacturing operations. It also minimizes the number of transformer failures upon initial connection to the power circuits.

THE USE OF impulse generators in developmental testing of distribution transformers prior to 1930 taught us much, but the process was painful. It was soon found that none of the recommended methods of failure detection was trustworthy and that the facts had to be determined by tearing down and carefully examining all insulation. The multilayered coils of relatively small wire were quite a different matter from the coil structure of larger transformers. Much skill was developed in analysis of failures and great impetus was given to studies of more rapid and dependable means of determining whether failures had occurred.

Some thousands of small transformers were sacrificed in these developmental studies, whose results were rapidly incorporated in the commercial product. A decade later a favorite test piece developed in the smallest rural unit, the $1^1/_2$-kva 7,200-volt transformer, which provided at least expense many of the coil characteristics which required study, some of these being accentuated by the small size of the coil and the conductor. One impulse generator was devoted almost entirely to this field. Accumulated knowledge made it possible to consider such matters as preferential location of ultimate failure, that is, within the coil or over major insulation, the coil arrangements for best distribution of transient voltages, and many details with regard to insulation.

The obtaining of consistent results from what seemed at first a matter of probability soon enforced certain precautions in the preparation of the test piece. Uncertain amounts of air and water may obscure other factors and play havoc with the intended results of changes. It became necessary in the interest of saving time to attempt a rather refined drying and degassing procedure so that the test pieces would be uniform in this respect.

This, in turn, raised questions as to whether carefully prepared test pieces were representative of units manufactured in quantity, and the question had to be resolved by extensive tests on transformers subjected to normal factory procedures only. This, in turn, had a great effect on manufacturing processes aimed at removal of air and water.

Thus, prior to 1945, thousands of small distribution transformers had been given impulse tests, most of them to destruction, and the coils torn down and carefully examined. In many cases the first cause of failure could not be determined because the voltages had been increased until the major insulation failed. Sometimes these first failures had been completely obscured by additional failures which followed. In spite of these handicaps, considerable progress was made during this early period.

IMPULSE VOLTAGE DISTRIBUTION

A GREAT DEAL of work was done in the early period of impulse testing to determine the impulse voltage distribution in various designs of coil structures. However, the technique was time consuming and expensive.

About 1940 the electric transient analyzer became available.[1] This device made it possible to determine the impulse-voltage distribution in a transformer winding quickly and accurately for most impulse-voltage wave shapes.

Impulse voltage distribution data are of particular interest to the design engineer because they permit him to place insulation where it is most needed.

NEUTRAL-IMPEDANCE FAILURE DETECTION

WITH THE ADVENT of the neutral-impedance method of fault detection in 1945,[2,3] impulse testing assumed a greater significance. Here for the first time was a technique of sufficient sensitivity to detect faults of minor magnitude. Some idea of the sensitivity of the method can be gained from observation of oscillograms, Figures 1*A*, 1*B*, and 1*C*. Figure 1*A* shows the voltage wave shape across a neutral impedance in series with a transformer high-voltage winding without a defect, and Figures 1*B* and 1*C* show varying degrees of fault.

Since the advent of the neutral-impedance failure-detection method, hundreds of transformers built for developmental purposes have been tested to detruction. The failures that occurred for these tests are classified in Table I.

IMPULSE TESTING AS A QUALITY-CONTROL TOOL

THE PROSPECT of using impulse testing as a quality-control tool has long been considered, but it was thought to be impractical because of the uncertainty of fault detection. Demonstration of the ability of electric apparatus to withstand impulse tests cannot be made unless adequate failure-detection methods are used. Prior to 1945, everyone who had occasion to make impulse tests had

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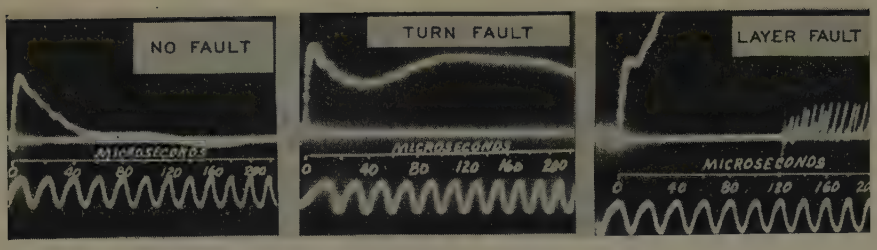

Figure 1. Impulse voltage wave across neutral impedance

at one time or another felt some uneasiness concerning the certainty of detecting small failures when utilizing the testing techniques then covered by the Standards.

Soon after the development of the neutral-impedance method of failure detection in 1945, an impulse-test equipment was built to be used primarily as a quality-control test for limited testing of small distribution transformers taken at random from the production line. In the period from 1945 to 1950, thousands of transformers were impulse tested. The failures that occurred on these transformers are listed in Table II.

IMPULSE TESTING OF COMMERCIAL TRANSFORMERS

In 1946, steps were taken to provide equipment to apply impulse tests to the high-voltage windings of distribution transformers rated $1^1/_2$ through 25 kva with high-voltage ratings of 15 kv and less manufactured at the Holyoke, Mass., plant of the General Electric Company.

Specifications for test equipment called for installation on a conveyor system having a time cycle of one transformer per minute. This equipment subjects each high-voltage bushing of the transformer high-voltage winding to two $1^1/_2$x40 microsecond impulse waves at a peak voltage equal to that specified for chopped-wave tests in the Standards. This voltage is approximately 15 per cent above the specified full-wave voltage level. Experience has shown that this type of test is more effective in weeding out defective distribution transformers than the standard test of two chopped waves followed by a single full wave.

Table I. Impulse Breakdown Tests on Development Transformers During 6-Year Period from 1946 to 1952

Type of Failure	Per Cent of Failures
Turn to turn	1.5
Layer failure	7.9
Failure between high-voltage sections	18.0
Major insulation failure	72.6
Total	100.0

Table II. Impulse Testing, Limited Random Sampling, of Commercial Transformers During 5-Year Period from 1945 to 1950

Type of Insulation Failures	Per Cent of Units Tested
Turn to turn	0.19
Layer failure	0.36
Terminal boards	0.17
Major insulation failure	0.39
Internal lead failure	0.22
Total	1.33

There is also the advantage that when faults occur, they will be detected. This is not always true for the standard test. Failures which occur during the chopped-wave tests cannot be detected immediately. These failures must be detected during the full-wave test which follows, and there is no assurance that the same failure will repeat. Consequently, there is the danger of damaging the transformer without detecting the failure.

In the case of those transformers having integral voltage protective devices, these are removed or rendered inoperative. This is done since they are tested elsewhere, and it is not desired to reduce the magnitude of the applied test for the purpose of quality control.

By this time the neutral-impedance method of failure detection had proved itself so sensitive that electronic circuits were developed which would indicate when even the smallest failure occurred. With these circuits it is no longer necessary to rely completely on the test man to make minute observations of the oscillographic trace to detect faulty transformers. This detection is now accomplished automatically and it is possible to apply impulse tests to transformers at production-line speed with the assurance that faults will be detected. Once the circuits are closed on the transformer under test, the sequences of testing and fault detection are performed automatically. The cathode-ray oscillograph is available for visual observation but is not essential since electronic circuits give alarms when faults exist. The arrangement of equipment to make such tests is shown in Figure 2.

Early in 1949 this equipment was put in operation in the Holyoke plant as a regular production test on practically all distribution transformers manufactured there. Over 185,000 transformers have been tested to date. The transformer failures that occurred are listed in Table III.

IMPULSE TESTS ON LOW-VOLTAGE COILS

Impulse testing of high-voltage windings, while providing an adequate test for that circuit, does very little toward testing the low-voltage winding. The induced impulse voltage which appears in the low-voltage circuits is entirely inadequate for searching out defects. It is generally recognized that low-voltage windings are even more susceptible to manufacturing defects due to burrs on heavy conductors, and the possibility of shears in layer insulation caused by greater winding pressures.

About 1940 considerable work was done experimentally to develop an impulse test which would apply impulses to the low-voltage windings of small distribution transformers, and which would stress the turns and layers of the high-voltage winding by induction. The test equipment was built and hundreds of transformers were tested. Approximately one per cent of the transformers that were tested failed due to faulty construction. These data indicate the importance of this type of test.

Since the original work on low-voltage testing was begun, other investigations have shown the manner in which light-

Table III. Production Impulse Test on Transformers Manufactured in Holyoke for 2 1/2-Year Period From May 1949 to January 1952

Type of Insulation Failures	Per Cent of Units Tested
Turn to turn	0.035
Layer failure	0.003
Between high-voltage sections	0.069
Terminal boards	0.120
Major insulation failure	0.221
Internal lead failure	0.451
Punctured high-voltage bushing	0.073
Total	0.972

ning surges arrive at distribution transformers in service.[4,5] These data show that a large per cent of these surges arrive at the transformer by means of the low-voltage lines. It emphasizes the desirability of a searching test on the low-voltage winding itself because in service the low-voltage winding is almost as likely to be subjected to lightning surges as the high-voltage winding.

For testing low-voltage windings, the Standards specify a full-wave impulse voltage of 30 kv. Due to the low impedance of the low-voltage circuits, it usually is not possible to apply 1 1/2x40 microsecond waves from terminal to terminal without an excessively large impulse generator. Furthermore, waves of such length would produce destructive voltages in the high-voltage windings. Therefore, the Standards permit the test to be made by connecting the low-voltage terminals together and applying the impulse from terminals to ground. This tests the insulation to ground, but not the internal insulation of the winding.

It has been found that the correct current low-voltage impulse wave to stress both the high-voltage and the low-voltage circuits adequately is a wave of approximately 0.5x1.5 microseconds length and 25-kv crest. Such a wave is applied to the *X3* terminal with the *X2* terminal at ground potential and the two low-voltage windings connected in series. Since the inductive coupling between the two low-voltage windings is very good, an equal and opposite voltage is induced between the *X2* and *X1* terminals. In this way it is possible to test the windings with an impulse voltage of 50 kv across the full winding without causing the bushings to flashover. A test of this type stresses the insulation between turns, layers, and coils in a manner not possible with a test from winding to ground. By induction and oscillation the turns and layers of the high-voltage winding are given an additional test, so the complete test consisting of both high-voltage and low-voltage tests is more thorough than the conventional impulse test.

Detection methods based on a new principle were designed which are as sensitive as those used for testing the high-voltage winding. In order to make failure detection automatic, electronic circuits were developed which give an alarm and interrupt the test when failure occurs. Experience with this type of test equipment in Holyoke showed such automatic features to be very essential.

As regards the test on the low-voltage windings, the short steep wave has been determined to be helpful in searching out defects, which is the purpose of a quality-control test. It probably does not as nearly represent the phenomena of natural lightning as does the standard wave applied to the high-voltage windings, but field records seem to indicate that very heavy discharges through low-voltage windings are exceedingly rare and are accompanied by disruptive mechanical effects when they occur. No effort to parallel the 1 1/2–40 microsecond wave used on the high-voltage windings seems justified or even practicable.

TESTS ON HIGH- AND LOW-VOLTAGE WINDINGS

In January 1950, impulse testing of low-voltage windings of transformers was added to the impulse test used for limited sampling of commercial transformers. In this 2-year period thousands of transformers were tested. The failures that occurred on these transformers are listed in Table IV. The percentage of failures shown in Table IV is somewhat higher than those shown in Table II and Table III because when weakness was found in a group of transformers, the testing effort was concentrated on that group.

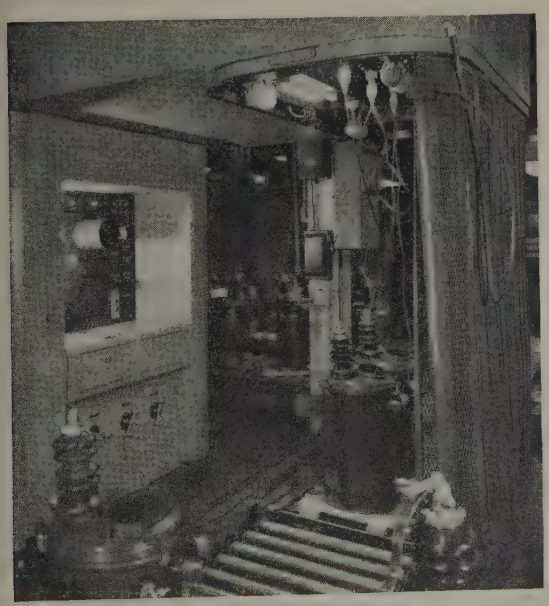

Figure 2. Two views of the automatic impulse testing of distribution transformers at the Holyoke Plant of the General Electric Company

Consequently, the failure record is higher than it would have been if the transformers had been selected at random.

The impulse tests on the low-voltage windings were made after the tests on the high-voltage windings. It is important to note that approximately 20 per cent of these faulty transformers would have been passed as good transformers if the impulse had been applied to the high-voltage windings alone. This is because the voltage induced in the low-voltage windings by the high-voltage impulse test was not sufficient to break down the faulty low-voltage insulation. Of the faults found by the low-voltage impulse test, 75 per cent were in the low-voltage circuits of the transformers.

TRANSFORMERS DEFECTIVE BY LOW-FREQUENCY TESTS

IT IS NOT UNCOMMON for transformers to fail during the low-frequency testing and for the faults to clear or seal up and not be reproducible.

Impulse testing has been used as a check on transformers which were shown defective momentarily during low-frequency testing. Of these cases, a high percentage of failures were due to faulty turn insulation which failed during low-frequency tests. These faults were due to a burr which burned clear and gave no further indication of trouble during low-frequency testing. We believe, however, that such a transformer would have a very short life in service and should be rejected. Failures detected by the impulse test on such transformers are listed in Table V.

Table IV. Impulse Testing, Limited Random Sampling, of Commercial Transformers Using Impulse Tests on Both the High- and Low-Voltage Winding During 2-Year Period From January 1950 to February 1952

	Transformer Faults Shown by Impulse Test	
Type of Defect	On High-Voltage Coils Per Cent of Units Tested	On Low-Voltage Coils Per Cent of Units Tested
High-voltage turn-to-turn failure	0.18	
Low-voltage turn-to-turn failure		0.09
High-voltage layer failure	0.33	0.06
Low-voltage layer failure		0.12
Between high-voltage sections	0.06	
Major insulation failure	0.21	
Internal lead failure, high voltage	0.90	
Internal lead failure, low voltage		0.03
Open circuit		0.06
Reverse polarity		0.09
Punctured high-voltage bushing	0.45	
Punctured low-voltage bushing		0.03
Terminal boards	0.06	
Total	2.19	0.48

Table V. Faults Detected by Impulse Tests on Transformers Previously Indicated But Not Proved Faulty by Low-Frequency Tests

Type of Failure	Failures Found by Impulse Test on High Voltage During Period 1946 to 1950 Per Cent of Failures	Failures Found by Impulse Test on Both High-Voltage and Low-Voltage Coils During 2-Year Period 1950 to 1952 Per Cent of Failures
Turn to turn	6.3	61.0
Layer failure, high-voltage coil	20.8	4.9
Layer failure, low-voltage coil		12.2
Failed between high-voltage sections	17.7	4.9
Major insulation	53.1	9.7
Internal lead failure	2.1	7.3
Total	100.0	100.0

The large number of turn failures detected when both windings were given impulse tests is of considerable interest. As would be expected, these turn failures occur more often in the low- than in the high-voltage windings.

IMPROVED FAULT-DETECTION IMPULSE TESTS

A REVIEW OF THESE DATA shows that the improved methods of fault detection are of great value in locating faults in distribution transformers.[3] Observation of the shape of the voltage wave as a fault detection method probably would have failed to find as much as 40 per cent of the defects shown by the improved methods.

PLAN FOR IMPULSE TESTING AND TEST EXPERIENCE

THE TESTING EQUIPMENT so far built can impulse test the high- and low-voltage windings of all single-phase distribution transformers up to and including 100 kva, with high-voltage windings 15 kv and below, and with low-voltage windings 600 volts and below.

The improved methods are very successful in detecting many types of failure during impulse tests. The following are among those detected: 1. Omitted or misplaced insulation. 2. Improper location of coil terminations. 3. Defective wire and turn insulation. 4. Sheared insulation due to winding pressures. 5. Malfunction of treating process for the removal of air and moisture. 6. Defective terminal boards, ratio adjuster, and porcelain bushings. 7. Open circuits. 8. Short circuits, sensitive to one turn, high or low voltage. 9. Partial coil failure between sections, layers, or coils.

CONCLUSIONS

EXPERIENCE WITH the use of impulse testing as a quality-control tool in the manufacture of distribution transformers leads to the following conclusions:

1. It is important to detect transformer faults regardless of their nature. This test functions as an invisible inspector and as a final check on manufacturing operations.

2. It minimizes cases where transformers fail when first connected to power circuits.

3. It has the effect of a high standard quality-control check on equipment which should further improve field operation under service conditions.

4. From its nature the impulse test cannot subject all parts of the insulation to uniformly high stress. Lightning stresses, however, are one of the principal enemies of transformers in service and a test carefully designed to simulate their effects should be of great value. It will assure that those areas of insulation subjected to such stresses will be designed against them and pretested as well.

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Multipoint Telemetering System Using Teletype Transmission

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The principle upon which this telemetering system functions is that the magnitude of a measured variable quantity is converted into a pulse of proportional time width and was developed for remote monitoring of pumping stations on a pipe line to permit automatic operation from a central dispatch office.

ELECTRIC telemetering has been used in the electrical industry for many years as a means of operating power systems, generating stations, and substations.[1] The applicaton of electric telemetering to the field of industrial processes, while relatively more recent, is becoming increasingly important. Processes which depend on telemetering for operation include the chemical industries, the making of iron and steel, the transmission and distribution of natural gas, the refining and transmission of oil and oil products, the operation of atomic reactors, and many others.

Short-range or local telemetering, frequently called remote metering, is commonly used inside large plants. Typical systems employ potentiometric and bridge balance circuits and electronically operated instruments as receivers. Air-operated telemetering for these applications offers strong competition to electric systems up to distances of several thousand feet, particularly for the measurement and control of the nonelectrical variables such as pressure, temperature, level, and flow. The electric systems have the advantages of greater range and almost instantaneous response; but since the accuracy and resolution is affected by the attenuation of the transmitted signal, the longest distances normally used are approximately 5 miles for a-c systems and up to 50 miles for d-c potentiometric systems. In applications where the system involves distances of the order of 100 or even 1,000 miles as, for example, an oil pipe-line system, measured quantities are converted into some factor of time such as the frequency of a periodic signal or the time duration of a pulse.

The system described in this article, while utilizing some of the devices of local telemetering, is of the long-distance time-factor type. Its operation depends on a number of principles which individually are not new in the present art of telemetering[2] but in combination result in a system of considerable flexibility, capable of telemetering measured quantities over commercial telephone or telegraph circuits or by radio link any desired distance.

The design of this system is basically of an electromechanical nature utilizing a minimum number of electronic components. Electronic amplifiers and relays are actually used only in the local receivers and in the sweep-balance detectors since the requirements of the specific application, as to speed and resolution, did not warrant an all-electronic system. However, it should be apparent that the general principle of operation of the system is not restricted to the specific design which was developed for the pipe-line application.

This long-distance telemetering system was developed as part of a co-operative project to provide completely automatic operation for pumping stations on a products pipe line of the Shell Oil Company running from Wood River, Ill., to Toledo and Columbus, Ohio. These pumping stations are controlled from the central dispatching office located in New York, N. Y.

The terminology employed in this article is taken both from the point-to-point and the mobile or radio telemetering fields and the choice of a term used in describing a principal function is selected on the basis of its accuracy and conciseness. It is important to note that basic principles of operation are common to both groups of telemetering and the differences in equipment exist principally because of the special techniques that are utilized in the two general systems. These differences in techniques depend primarily on the differences in requirements which exist between these two general fields of application. From the technical standpoint it is believed that mobile telemetering has become the leader to a considerable extent principally because of its utilization of the high speed of response, compactness of design, and mobility of the radio link. Consequently, it is expected that mobile telemetering in the future will influence the design of point-to-point or ground systems to a considerable extent. Furthermore it is probable that systems, which were developed for very high speed telemetering a multitude of quantities important to the flight test of a controlled missile, will be applied in modified forms to industrial telemetering systems. Obviously, differences of design continue since factors such as size, weight, and high-frequency response are not critical in the stationary systems; whereas long life, reliability, ease of service by nonelectronic personnel, and other factors are important in the industrial field.

Essentially full text of paper **52-197**, "A Long-Distance Multipoint Telemetering System Using Teletype Transmission," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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The authors wish to acknowledge the assistance given to them in the preparation of this article by engineers of Shell Oil Company, General Electric Company, and American Telephone and Telegraph Company, all of whom collaborated in the design of the telemetering and supervisory control system for the pipe-line pumping stations of the Shell Oil Company's East Line.

THE BASIC SYSTEM

The telemetering system described in this article is essentially a combination of local telemetering units of the servo-actuated position type[3] coupled to a long-distance system which operates on a general principle of what the mobile telemetering engineers call a time division–pulse coded multiplexing system. Actually, it is also what the point-to-point telemetering engineers designate as an impulse duration multiplex or multipoint system. In this scheme each measurand (measured quantity) is sampled in a sequence by means of a scanner and then transmitted to the final receiving station or stations as a series of coded characters. Each channel of information is identified by the code selected and each measurement of the various quantities is sampled in sequence and transmitted as a complete series of coded characters by converting the width of the pulse as determined by the scanner into a proportional number of coded characters. Figure 1 is the basic diagram of the system. The measurands may be electrical but in process industries are more frequently nonelectrical quantities such as pressure, flow, level, and so forth. Each of the quantities is converted either directly or through several stages of local telemetering into an electrical quantity proportional to the original variable. The outputs of all the transducing or converting elements in the system are of the same nature so that they can be compared against a common scanning function. The sequence switch, commonly called the commutator or sampler, automatically and in a predetermined sequence connects each of the transducers into the scanning circuit where a comparison is made between their outputs and the time-varying output voltage of the scanner. If the output of the pickup is a voltage directly proportional to the measurand, the output of the scanner during the rise period is made a linear function of time. As will be explained in detail later, the function of the scanner is to convert the magnitude of the output of each transducer into a proportional time pulse.

The proportional time interval is represented by the time of dwell of an electric contact in this system but also may be represented by the period of conduction of an electron tube. This pulse may be transmitted without further modification over a wire link. If a radio link is used, an amplitude- or frequency-modulated carrier is required.

The transmitted quantity may be identified at the receiver by its chronological position in a train of impulses such as might be indicated on a cathode-ray oscillograph. In the specific system, developed for the pipe-line telemetering, identification is accomplished by converting each pulse into a group of coded Teletype characters. The coding is accomplished by synchronizing the Teletype equipment with the sequence switch.

PICKUPS

There are many primary detectors or pickups in use today whose purpose is to convert the measurand to some electrical quantity which can be conveniently measured. Figure 2 shows a number of the transducers, which convert the process variables, such as pressure and flow, to proportional alternating voltages by means of differential transformers, whose output voltages are proportional to their core position.[3]

The pickups shown are employed where the basic measuring elements are mechanical devices such as a bellows, Bourdon tubes, floats, and so forth. This type of mechanical link produces a position or motion proportional to the measurand which is then converted into an electrical variable by means of the adjustable-core transformer coupled to the mechanical device. It will be noted that these systems represent two and sometimes more stages for the conversion of the measurand into an electrical variable. On the other hand, pickups such as thermocouples and resistance thermometers are primary detectors which perform the conversion in a single stage.

Figures 2*A*, 2*B*, and 2*C* show pickups whereby pressure, differential pressure, and flow, respectively, may be measured and converted to proportional voltages. For variables such as pressure and level, the arrangement shown in Figure 2*D* is suitable if a record is desired at the transmitter. In the case of nonlinear variables, a secondary pickup is employed as indicated in Figure 2*E*. Here

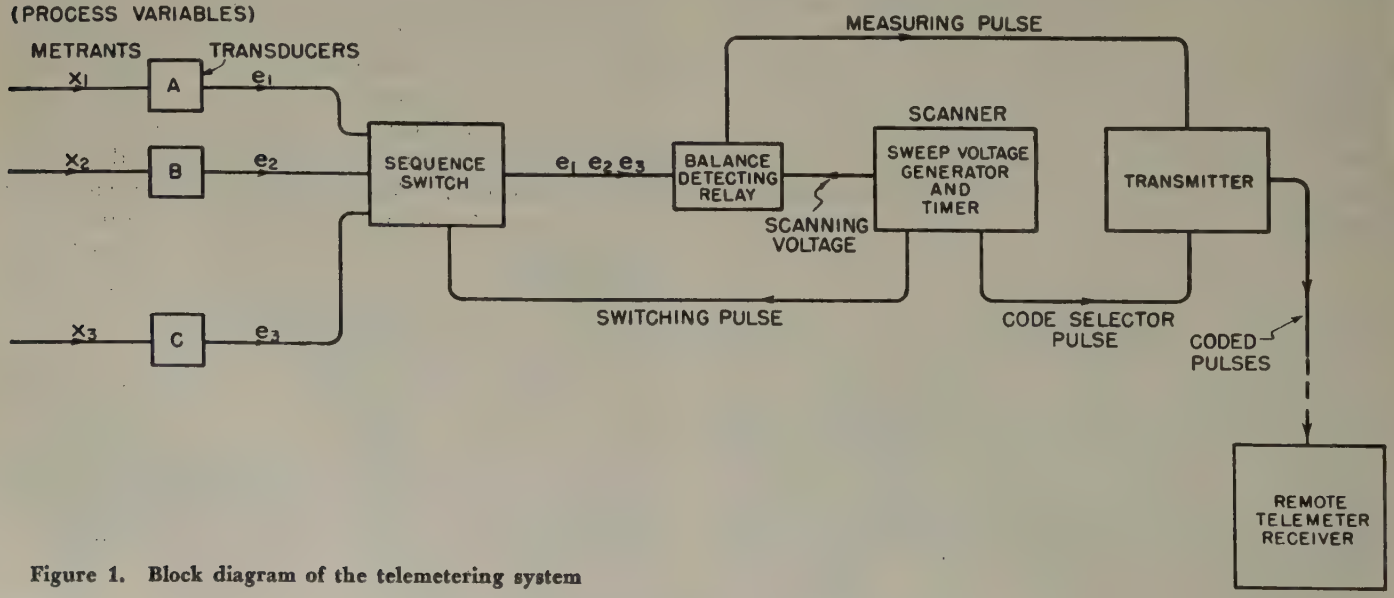


Figure 1. Block diagram of the telemetering system

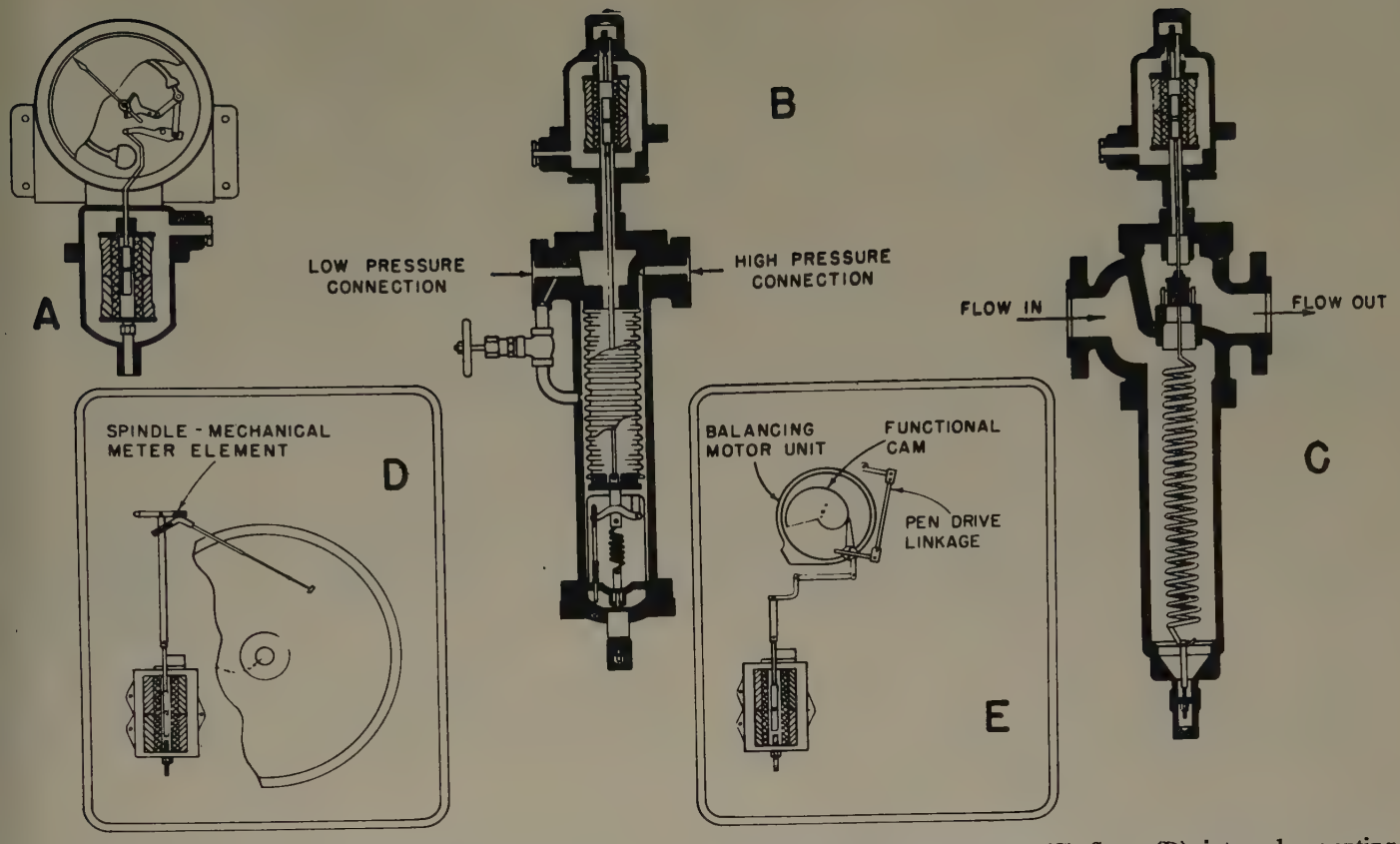


Figure 2. Pickups of the differential transformer type: (A) pressure (B) differential pressure (C) flow (D) internal mounting in mechanical meter (E) internal mounting in electronic-type recorder

the primary detector is balanced by a motor-driven slide-wire unit and retransmitted to the differential transformer by means of the correct nonlinear-function cam to give an output voltage which varies linearly with the measurand.

Figure 3 shows several pickups of the resistance type. The resistance thermometer and the strain gauge are primary detectors in which the resistance varies directly with the measurand. The pressure pickup shown by Figure 3*C* functions by positioning the slider of a low-torque potentiometer. Figure 3*D* shows the manner in which a retransmitting slide-wire is actuated by the motor of a self-balancing recorder.

THE SCANNER

The scanner as shown in Figure 4 consists of a synchronous motor driving a linear rise cam which actuates the core of the differential transformer in such a way that its output voltage varies proportionally with time. A second cam, mounted on the same assembly as the scanning cam, actuates the timing microswitch. The two cams are so arranged that at the instant when the differential coil output voltage is passing through zero, the microswitch will close and will remain closed until after the scanning voltage has exceeded 100 per cent. The opening of the timing microswitch initiates the switching sequence. After an interval required for this operation it closes once more to begin the timing cycle for the next variable.

The secondary of the scanning transformer is connected in turn to each of the pickup transformers by a sequence switch, or sequentially operated relays. The scanning transformer and the pickup transformer are connected to obtain a voltage proportional to the difference of their outputs. This difference or error voltage is applied to the electronic relay. This relay is so arranged that when the input voltage to it is of one phase, its output relay coil is de-energized, and at the instant the phase changes, the relay is energized, closing its contacts.

The scanner operates in the following manner. Starting

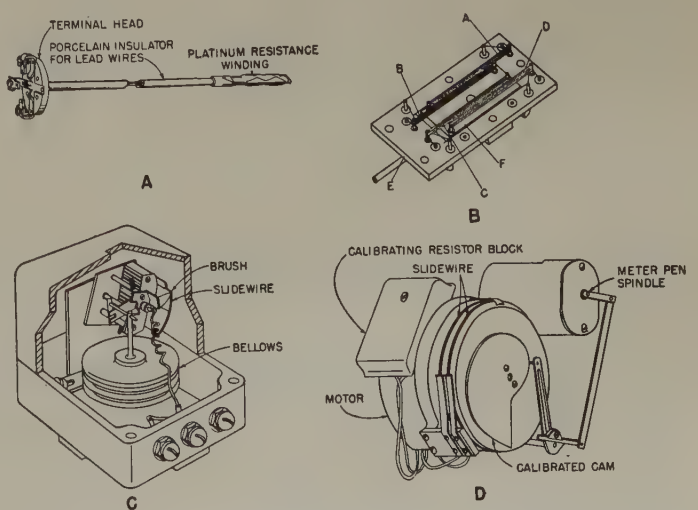


Figure 3. Pickups of the resistance type: (A) resistance thermometers (B) strain gauge of Statham unbonded type (C) pressure pickup of Gianinni type (D) motor-driven slide-wire balancer and retransmitter

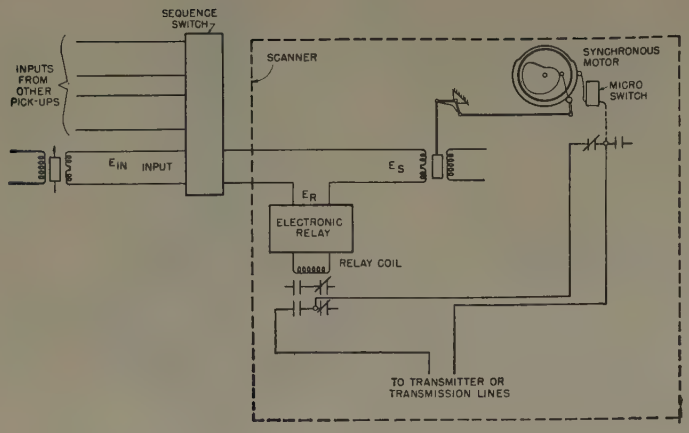


Figure 4. Elementary diagram of the scanner

at time equal to zero, when the timing microswitch closes, the scanning voltage is zero and begins to increase linearly with time. The voltage to the electronic relay is a maximum at $T=0$ since

$E_r=E_{in}-E_s$ and at $T=0$, $E_s=0$

This relay voltage will decrease linearly with time as the scanning-coil voltage increases and approaches the value of the output voltage of the pickup. At the instant when the two voltages are equal, the electromagnetic relay on the output of the electronic unit will be de-energized thus opening the circuit to the transmitter or transmission line and completing the period of transmission of intelligence.

The curves of Figure 5 indicate diagrammatically the operation of the electronic relay. Three curves of relay input voltage (for three different signal inputs) on a time base are shown in Figure 5*B* showing how the magnitude of the signal voltage determines the pulse length. Figure 5*C* depicts one cycle of the scanning voltage.

Over the measurement interval the reference voltage of the scanner is given by the equation:

$$e_s/E_s=t/T_0 \qquad (1)$$

where

e_s = the voltage output of scanner at time t
E_s = the voltage output of the scanner at time T_0, the end of the scanning period

The output of the linear transducer is given by

$$e_x/E_x=x/X_0 \qquad (2)$$

where

e_x = voltage output of transducer at a value of variable x
E_x = voltage output of transducer at a value of variable X_0 (100 per cent)

The duration of the measurement contact is obtained by equating e_s to e_x and solving for t. Hence

$$t=(E_x/E_s)\,(x/X_0)\,T_0 \qquad (3)$$

If

$E_s=E_x$,

$$t=(x/X_0)\,T_0 \qquad (4)$$

Equation 4 shows that the duration of the measurement contact is directly proportional to that of the measurand, x.

If the output of the transducer is a nonlinear function of the measurand, this function can be extracted by using a servo-actuated receiver to operate through a cam, the core of a retransmitting transformer. For example, the voltage output of the differential transmitter shown by Figure 2*B* is proportional to the square of flow. In this case the retransmitter cam has a square-root rise characteristic so that the output of the retransmitter transformer will be proportional to flow. If, however, all of the quantities to be scanned have the same nonlinear characteristic, the cam of the scanning unit may be shaped so that its rise is a similar nonlinear function of motor shaft rotation. For example, in the case of the differential-type flow meter

$$e_x=E_x(x/X_0)^2 \qquad (5)$$

If the rise of the scanning cam is made proportional to the square of the angle of rotation of the scanning motor shaft,

$$e_s=E_s(t/T_0)^2 \qquad (6)$$

Consequently, if $E_s=E_x$, the electronic relay will be energized for the period, t, obtained by equating equations 5 and 6.

$$t=(x/X_0)\,T_0 \qquad (7)$$

as in the linear system.

It is entirely feasible to use a rotating slide-wire as the scanner device, and for high-speed telemetering a calibrated electronic generator could be used. For the requirements of the pipe-line telemetering system, the cam operated scanner has a number of basic advantages such as elimination of sliding contacts, ruggedness, and ease of calibration.

TRANSMISSION LINK

One method by which the intelligence may be transmitted and coded is by the use of the Teletype

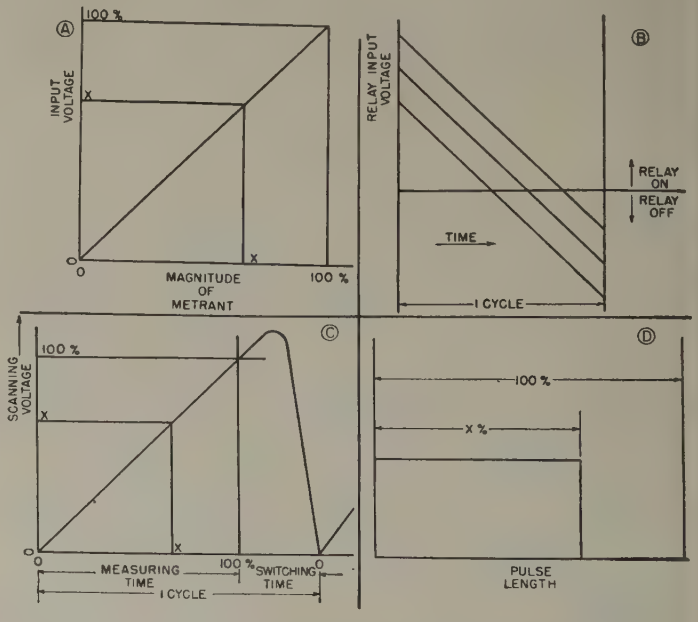
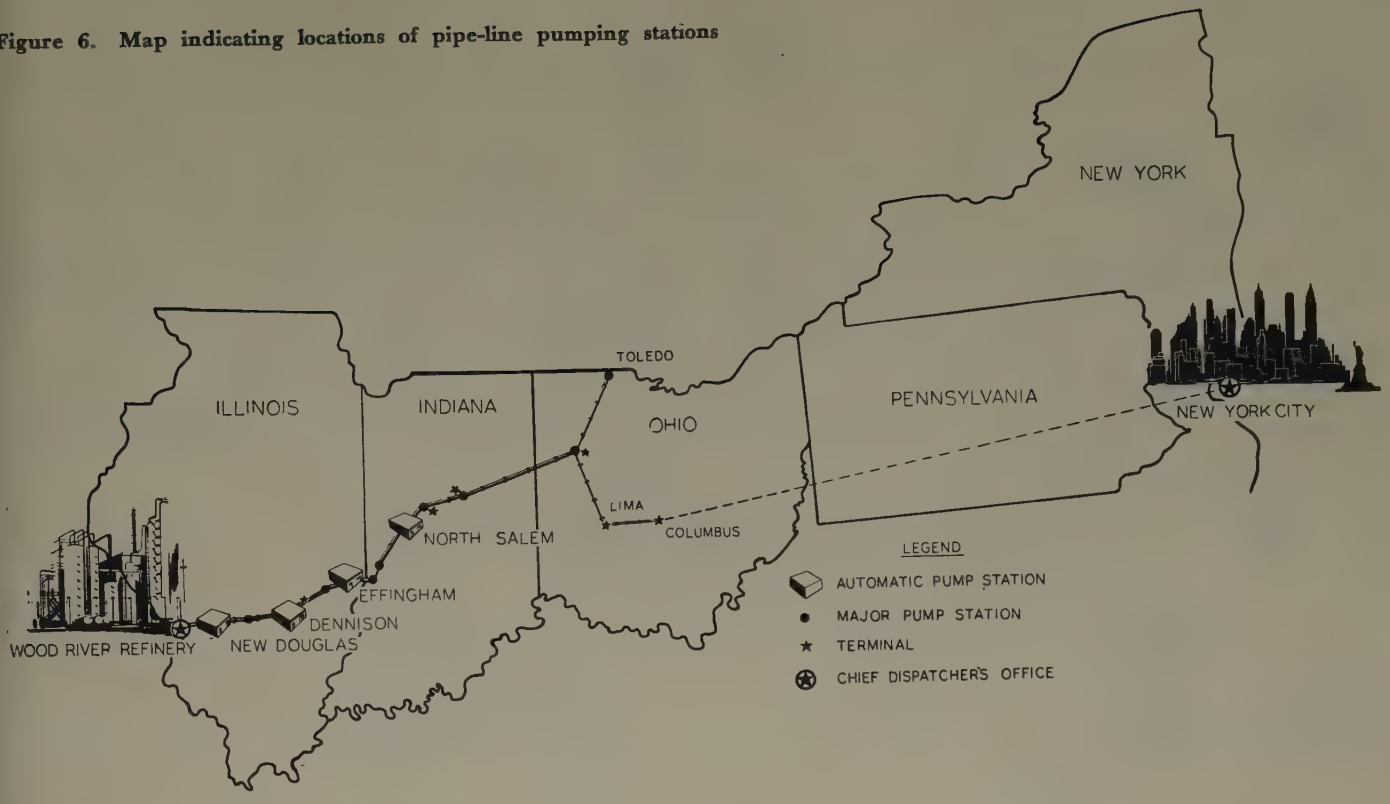


Figure 5. Graphs of process magnitude, voltage-time relationships

Figure 6. Map indicating locations of pipe-line pumping stations



system. While a detailed explanation of the various circuits used to achieve this is beyond the scope of this article, the general operation of the system is as follows.

An electric contact whose duration is proportional to the measurand is supplied by the electronic balance detecting relay of the scanner to the Teletype transmitting equipment. The Teletype apparatus sets up coding letters for each variable such as shown using the letter *S* for suction pressure, *T* for temperature, *F* for flow, *L* for level, and so forth. The equipment starts printing at a constant rate the appropriate letter at the beginning of the scanner timing cycle and stops when the scanner contacts open. Thus, the number of letters in any one sequence is proportional to the variable. At the end of the transmission of intelligence, a code letter such as *PQ* is sent to indicate the location of the transmitter in cases where there may be similar intelligence channels from other remote stations.

SSSSSSSSSSSSSSSSSS PQ
TTTTTTTTTTTTTTTTTTTTTTTT PQ
FFFFFFFFFFFFFF PQ
LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL PQ

The Teletype channel has the advantage of using comparatively standard equipment and easily furnishing the intelligence required both at the transmitter and receiver and all other Teletype sets connected to the particular network. It has the disadvantage that the resolution is limited by the speed at which the Teletype may be operated. In most cases, however, this is not a serious drawback.

PIPE-LINE APPLICATION

This system was first used on automatic pumping stations for a pipe line of the Shell Oil Company. It is installed, as shown in Figure 6, on the four automatic booster stations located at New Douglas, Dennison, and Effingham, Ill., and North Salem, Ind. The stations make possible a much higher throughput than usual in an 8-inch line, as well as increasing over-all operating efficiency.

The operation of the four stations is entirely controlled from the central dispatch center in New York City. Various products are pumped in turn through the line and it has been found that the slight intermixing produces no harmful results in the quality of any of the products. The location of these products is traced on a control board which simulates the pipe line. Thus, the dispatcher in New York has a completely integrated picture of the location and quantity of all products in the whole pipe line as well as the pressures and pump motor current of each of the four booster stations. Since the dispatcher has control of these stations, as well as complete operating information, he is in a position to operate the line in a more efficient manner.

The telemetering equipment, as previously described, furnishes information regarding suction pressure, discharge pressure, and pump motor current. A block diagram, Figure 7, indicates the telemetering equipment supplied for each of the four booster stations. The suction and discharge pressures are measured by gauges installed in the pump house and locally telemetered to the control room where they are recorded. A motor current recorder is also located on the same panel. Electrically isolated voltages from the three transmitting differential transformers are connected to the sequence relay and in turn to the scanner for long distance telemetering. A simplified schematic diagram, Figure 8, outlines the circuits used

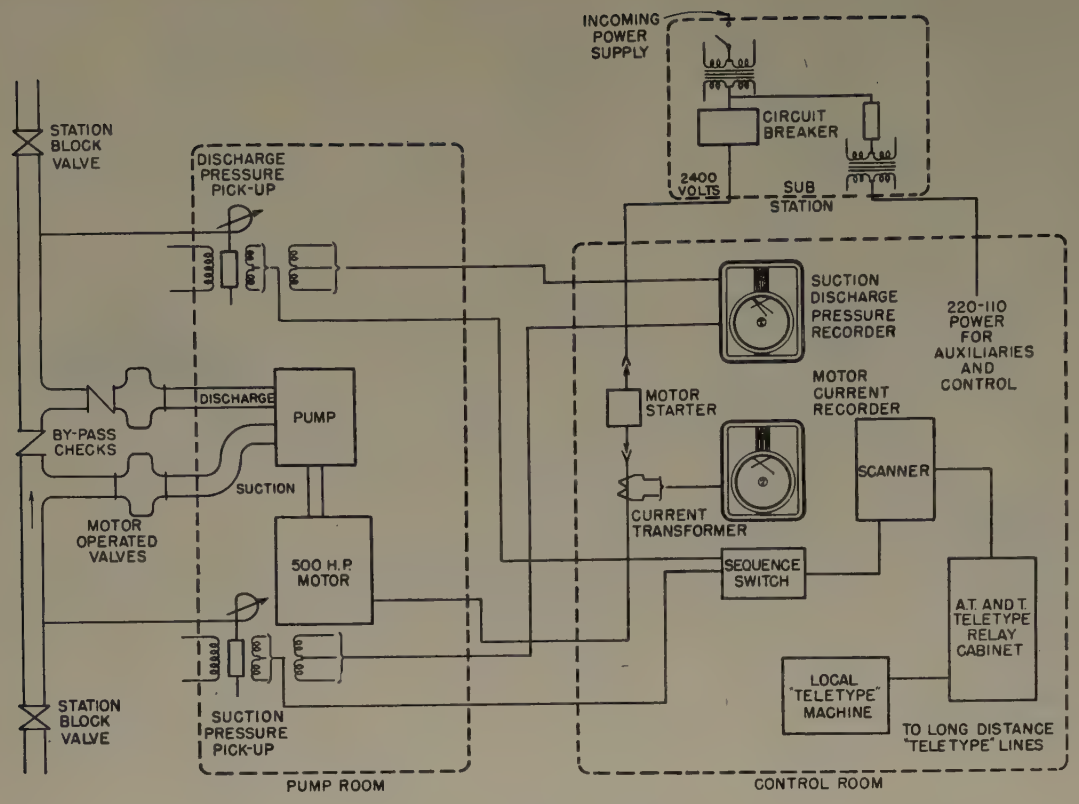


Figure 7. Simplified block diagram of station arrangement

in the measuring and telemetering equipment supplied by Bailey Meter Company.

In order to obtain readings of telemetered variables, the dispatcher at New York City dials a code number which operates the equipment at any one of the four chosen stations and automatically telemeters the pressures and pump motor current in the form as shown previously. At the end of one telemetering cycle of the three variables, the equipment automatically shuts off and the dispatcher then may obtain, if he desires, similar information from the three other stations. The dispatcher also may start and stop the main pump motor, lubricating oil pump, suction and discharge valves, and other necessary equipment. In an emergency, he also may sound a siren to summon the operator who is located at each station for maintenance and emergency purposes.

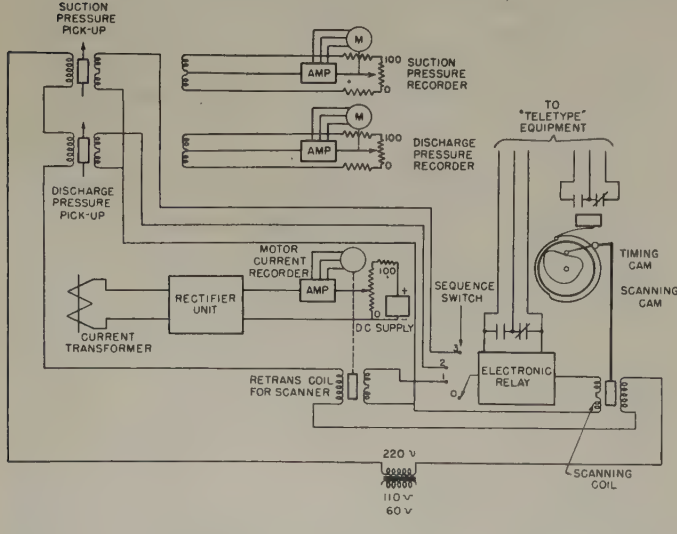


Figure 8. Simplified schematic diagram of telemetering system

All the information received in the New York dispatcher's office is simultaneously printed on all the other Teletype machines which are connected to the same system. The Teletype machine is operated at a speed of 368 characters per minute or 163 milliseconds per character. The total cycle period for the scanning of one measurand is 15 seconds or 45 seconds for a complete intelligence report from any one station. The 100-per-cent measurement time was selected at 60 characters or 9.783 seconds. Thus, the resolution of the system is one part in 60 or approximately 1.7 per cent. The remaining portion of the cycle, 5.2 seconds, is allowed for the various switching operations involved to transfer from one pickup to the next, change code letters, and so forth. If a lower resolution were permissible, the cycle time could be proportionally reduced, and similarly for a higher resolution, a longer cycle would be employed.

This system has been in operation since September 1950. Some trouble was experienced at the beginning with servo-amplifier failure, caused by faulty components, but this was easily remedied since these units are standard plug-in assemblies. Since then the equipment has been found to be completely reliable due to its inherently simple nature, lack of delicate components, and over-all ruggedness. It serves its purpose admirably in integrating all information and supervisory control at one centralized point and thus permitting much more efficient utilization and operation of the pipe-line system.

CONCLUSIONS

It will appear obvious perhaps to the electronic engineer in the field of mobile telemetering that the utilization

of electronic techniques could have been made in any or all of the elements of the system described. For example, an electronic scanning system could have been used in place of the electromechanical system, resulting in much greater speed of scanning. Acceptance of complex electronic systems for the control and telemetering of industrial process variables has been somewhat slow, particularly where the requirements do not exclude the use of simpler electromechanical mechanisms. Where high speed and sensitivity are required and a great number of variables are to be telemetered, the electronic systems probably would be required.

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The Phosphor-Phototube Radiation Detector

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Ionizing radiation detectors of all types are becoming of increasing importance and the most important types for portable radiation detectors have been ionization chambers and Geiger tubes. Herein is described a new portable detector, the phosphor-phototube type, which is a novel development.

THE FORERUNNER of the phosphor-phototube detector, the so-called scintillation counter detector, was proposed by Marshall and Coltman of the Westinghouse Research Laboratory after a routine survey of the properties of X-ray detectors early in the research program on the X-ray image amplifier, the Fluorex. It was reasoned that if an X-ray image amplifier was to be feasible, it would very likely involve as its basic detecting mechanism, principles found in one or more detectors then known. Among the detectors studied was that used for radiographic exposure monitoring in photofluorographic units. This simple detector consisted essentially of a commercial multiplier phototube "looking at" a fluorescent screen. It was rugged, inexpensive, reasonably stable, and nontemperamental in its operation, and it gave an excellently fast response. However, it was assumed to be rather insensitive and, therefore, suitable only for applications involving very high intensities.

As this photomultiplier X-ray detector was pushed to high sensitivity, an early demonstration showed that under high energy X-ray conditions, it could outdo a Geiger counter in detecting a feeble pulse of X rays through a pinhole, the Geiger counter being at a disadvantage here because of its poor X-ray absorption.

Studies of efficiency and spectral response of photosurfaces and fluorescent screen materials provided the surprising result that the average yield of photoelectrons was more than one for each X-ray quantum scintillation at the fluorescent screen. Thus it was possible to announce, in December 1945, at the meeting of the American Physical Society commemorating the 50th anniversary of Roentgen's discovery of X rays, that the new detector should be seriously considered as a primary research detector capable of approaching the ideal condition by which each single X-ray quantum contributes a registered signal. It also had the special feature of being able to resolve short-time X-ray events, then as short as 10 microseconds, which could not be approached by conventional Geiger counters and ionization chambers.

Alpha particle scintillation pulses were readily detected with the new instrument but were not considered especially significant, since they had long been observed and counted visually. By careful attention to four factors—selection of phototubes, choice of phosphor, design of an efficient optical light collecting system, and design of a circuit with time constants adjusted to the scintillation pulses—Coltman and Marshall thereafter were able to detect and discriminate from noise pulses due to electrons thermally emitted at the photocathode, the scintillation pulses of a number of radiations, including X rays, gamma rays, and beta rays. This scintillation counter was described in June 1947, at the Montreal meeting of the American Physical Society at McGill University where Rutherford had performed most of his pioneer experiments on alpha scintillations at the turn of the century.

It was later learned that Hartmut Kallmann had independently arrived at the scintillation detector in Germany, publishing later, in July 1947. Paying less attention to

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circuitry and efficient light collection, he had carried the phosphor selection into thick blocks of organic phosphors to gain better absorption and light yield from high-penetration radiations.

During 1948, a group of engineers were working at the Westinghouse Research Laboratory on a United States Navy investigation project to study and report on circuits and equipments for fixed or mobile installations to indicate the intensity of alpha, beta, and gamma radiations over a considerable intensity range. In the course of this work, the phosphor-phototube detector was further investigated. To the best of our knowledge, it was during this period that the method of detecting and measuring radiation by noting the average phototube current from a phototube being acted upon by the light from the phosphor first was used. It was described as a "phosphor-phototube" type of detector as opposed to the scintillation counter. A painstaking study of all the then known methods for radiation detection led this group to recommend "that an intense investigation and development of the phosphor-phototube type of detector be undertaken. This should include a search for the most suitable phosphor and the design of the phototube specifically for use as a radiation detector."

By January 1949 the results of this development had been sufficiently promising to justify the establishment of an additional task, that of developing a portable battery-operated radiation detecting instrument utilizing the phosphor-phototube detector method.

It was recognized that Geiger tubes usually suffer from a very serious defect when they are used in survey instruments in that their characteristic of "blocking" at high-intensity radiation might cause an instrument to read a low value when the actual field was quite intense. Ionization chambers require very high values of input resistance with the resultant serious problems of leakage and sluggish meter response due to long time constant.

It was believed that the phosphor and phototube method was particularly applicable to the so-called high-range portable detector for the detection of gamma radiation in the ranges 0 to 0.5 roentgen per hour, 0 to 5, 0 to 50, and 0 to 500 roentgens per hour. An experimental model

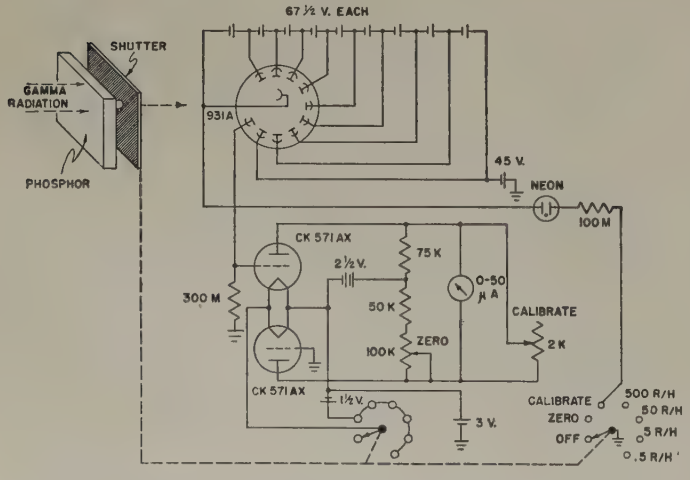


Figure 1. Diagram, experimental model

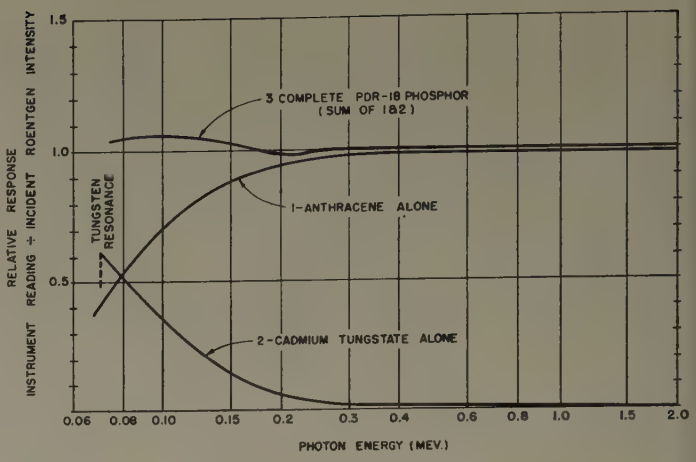


Figure 2. Energy dependence of PDR-18 phosphor: abscissa—photon energy (million electron volts); ordinate—relative response, the ratio of instrument reading to incident roentgen intensity

of such an instrument was constructed and operated with sufficient satisfaction to justify evaluation of the instrument by the Bureau of Ships at the Hunter's Point Naval Radiological Defense Laboratory.

This early model (see Figure 1) utilized a balanced-bridge current amplifier consisting of a pair of *CK 571AX* tubes with the indicating instrument connected across the plate of the tubes in a conventional vacuum-tube bridge circuit. The high voltage for the *931A* phototube was furnished by a group of $67\frac{1}{2}$-volt hearing-aid batteries. Filament voltage and bias supply were likewise furnished from batteries. Sensitivity changing was handled by actually changing the area of the phosphor which was allowed to be exposed to the photocathode of the *931A*. The shutter was mechanically connected to the meter scale-changing switch and was provided with apertures of the ratios 100, 10, 1, and 0.1 in area.

Although it was recognized that many problems lay ahead, considerable optimism for the future of the phototube-phosphor portable survey instrument was felt. It was decided that the development of such an instrument should proceed. The new instrument was to be known as the *AN/PDR-18*. At this time the known problems were principally related to the phosphor and methods by which the chosen phosphor could be used over a sufficiently wide temperature range to provide a useful military instrument.

The detailed requirements of the phosphor as they were then known were approximately as follows:

1. The light output from the phosphor when exposed to gamma radiation should have the same or approximately the same spectral distribution as that to which the cathode of the phototube is most responsive.
2. The change in light output of the phosphor with temperature should be a minimum over the temperature range.
3. The roentgen response must be reasonably flat to gamma energies from 0.08 to 2.0 million electron volts.
4. The phosphor must be reasonably free from chemical deterioration under normally encountered conditions.
5. The phosphor must be free from prolonged afterglow.

6. The phosphor should have a high light transmission for its own fluorescent radiation.

7. The phosphor must be large enough to provide a reasonable output at the lowest radiation intensities to be used.

8. The phosphor must not be susceptible to damage due to physical shock or temperature changes.

9. The phosphor must be available in sufficient quantity and have an economical price.

The search for phosphor narrowed down to naphthalene, anthracene, thallium-activated potassium iodide, calcium tungstate, and cadmium tungstate.

Anthracene appeared to be a good choice among the organic phosphors because of the linearity of response over a wide energy range. Cadmium tungstate has a flat response to lower temperatures than calcium tungstate. It was found that a combination of anthracene and cadmium tungstate could be arranged to give a virtually flat response over the energy region from 0.08 to 2 million electron volts. The combination of the two phosphors turned out to be comparatively easy in that the main phosphor can be anthracene with the addition of a small amount of cadmium tungstate crystals to the distal surface of the anthracene.

Figure 2 shows the energy response characteristics for cadmium tungstate and for anthracene. The ordinate is relative response and the abscissa is the energy of the radiation. Note that cadmium tungstate shows a rapid increase in response in the regions around 0.1 million electron volt while anthracene reaches a peak and drops off sharply in the region just below 0.1 million electron volt. Several other considerations are used in arriving at the final flat response, namely, choice of optimum thickness of the phosphor, optimum transmission within the phosphor, and added filtration.

The difficulty of obtaining large (1 by 1 by 1/4 inch) anthracene phosphors with good light transmission led to investigation of the possibility of embedding small crystals of anthracene in a transparent package. This method has proved to be entirely satisfactory and the phosphors are

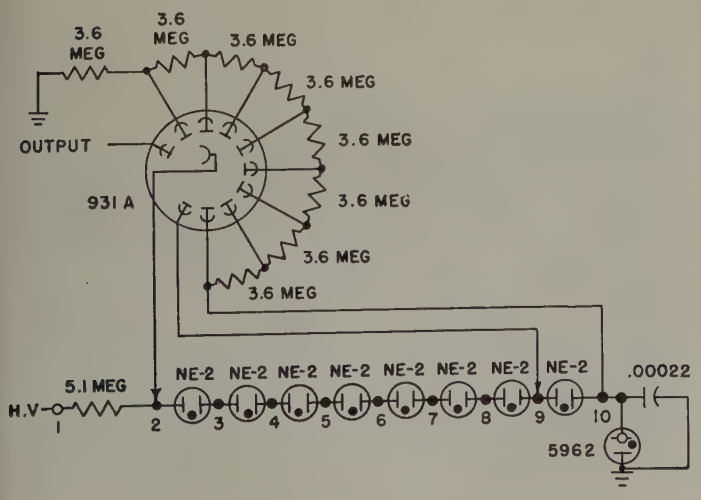


Figure 3. High-voltage connections to phototube

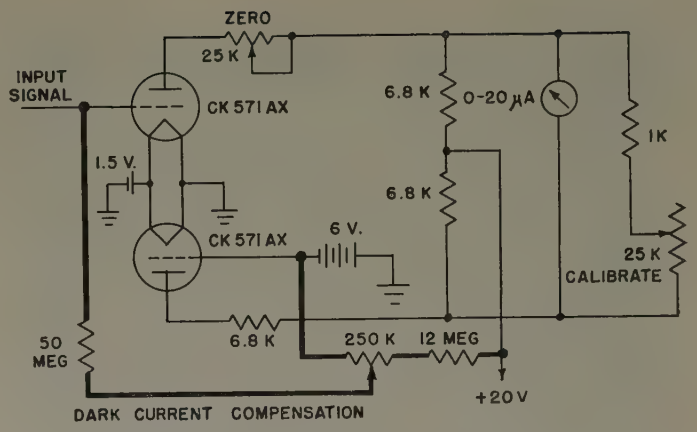


Figure 4. Amplifier with dark current compensation

all being prepared in this manner. The plastic covering ensures against internal changes in chemical structure related to environment.

To increase the light output, experiments were made with reflecting coatings on anthracene crystals. It was found that aluminum foil over the crystals increased the light output by 73 per cent but surprisingly enough it was also found that a highly reflecting white lacquer covering increased the output by 95 per cent. This increase of the lacquer over the aluminum foil is believed due to a reduction in light trapping because of a more intimate contact with the consequent reduction in air space between the lacquer and the crystal than is possible with the aluminum foil, and to the increased scattering of light as it is reflected.

Since the characteristics of a photomultiplier tube are such that a change in voltage produces a 7-power change in output current and since it was early found that different phototubes of the same type showed a rather wide variation in sensitivity requiring voltage adjustment to obtain a standard sensitivity, it was decided that the high-voltage power supply must be both stabilized and must permit ready adjustment of the dynode voltage to accommodate the sensitivity of the particular phototube used.

In the arrangement of Figure 3 the 55-volt neon lamps are utilized as voltage-stabilizing circuit elements and are also available as taps to facilitate adjustment of the voltage across the dynodes *1* and *2*. A stable voltage exists across the circuit path consisting of one 700-volt *5962* Corona regulator tube and eight 55-volt *NE2* tubes in series. The *NE2* tubes are processed before they are used by running them for 350 hours to obtain a permanent stable operating point. Incidentally, the use of the neon lamps across dynodes *1* and *2* resulted in a reduction in the power utilized by the phototube high-voltage circuit, since the use of resistance dividers at these points was not necessary.

The so-called dark current of the phototube or that anode current which exists with no light on the photocathode, was known to be a problem at the outset, particularly at the higher temperatures. In an application of the phototube-phosphor detector to a fixed equipment, it was possible to utilize a mechanical light chopper between the phosphor and the phototube and thereby dis-

criminate against the dark current. This mechanical chopper method is quite practical for larger equipment but is not thought to be applicable to portable survey instruments.

It was soon noted that the characteristic of any particular phototube which was pertinent to the problem of dark current was not the dark current of the phototube at a definite dynode voltage value, but rather the dark current when the dynode voltage was adjusted so that the phototube was operating at a given sensitivity. This is a typical situation. The factor which actually describes the merit of the device is the ratio of the signal as the tube is adjusted for use to the noise under these conditions. The Radio Corporation of America has adopted testing of *1P21*'s on this basis and any of these tubes can be used without selection in the *AN/PDR-18*.

The input voltage to the grid of the amplifier is a composite voltage of signal and dark current. Since the voltage developed by the dark current is essentially constant over the operating range of the detector, it is possible to balance out this voltage for any given temperature by applying an out-of-phase voltage of equal magnitude. The compensating voltage is obtained from a variable voltage divider, of proper polarity, and applied to the grid through a high impedance so as not to upset the grid circuit shown in Figure 4. The dark current is a function of the operating temperature of the photomultiplier tube. It is readily apparent that with linear-type resistors in the compensating network the developed voltage is independent of temperature changes, therefore, once the compensating voltage has been adjusted to the voltage developed due to the dark current, it will correct only over a limited temperature range. This condition is overcome by using a temperature sensitive device, such as a thermistor, in place of a linear resistance. We now have a compensating voltage that is a function of temperature and will balance out the voltage due to the dark current over an extended temperature range.

It will be remembered that the phosphor was separated from the phototube in the experimental model by a shutter whose position was controlled by the range-selecting switch of the instrument. It was noted that with this arrangement the dark current always represented the same absolute error on all scales. A more serious problem was the one of direct response from the phototube. The *931A* or *1P21* type of photomultiplier tube shows a small

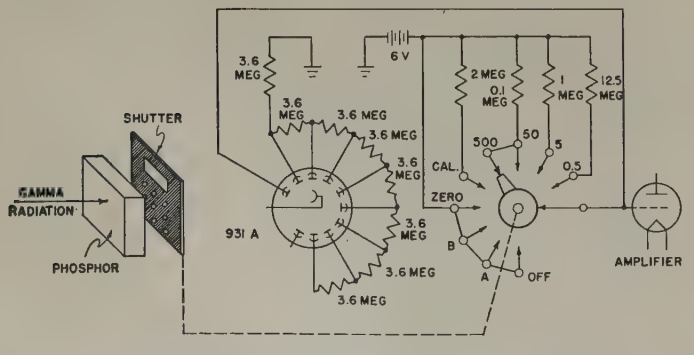


Figure 5. Shutter in 500 roentgens per hour position

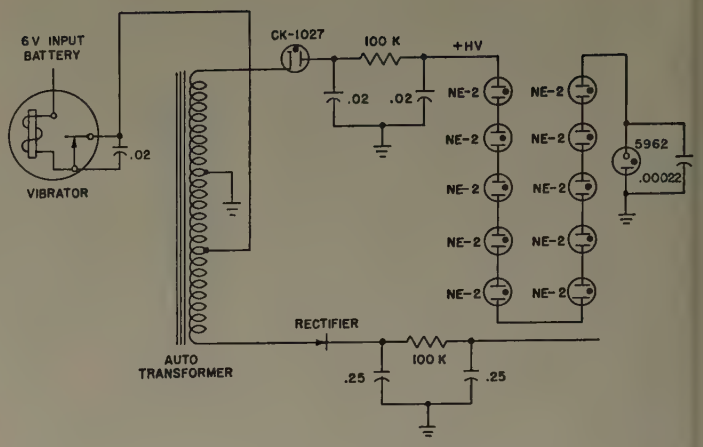


Figure 6. Power supply and regulators

but quite measurable direct response to gamma radiation. In fact a complete instrument has been constructed by the Naval Radiological Defense Laboratory using a photomultiplier tube as the sensitive element. With the multiple apertures a point was reached at which the direct response from the phototube was equal to the response from the phosphor, since, as the radiation field increased in its intensity, the proportion of light from the phosphor was continually being decreased whereas the direct response of the phototube component was undiminished. This is only a problem when it is carried beyond two decades and is not a serious problem until it is carried beyond three decades. For these reasons the input circuit to the amplifier grid was modified to utilize three different grid resistors for the first three decades and aperture shuttering is only used (Figure 5) between the 50 and the 500 range. The use of a shutter at the high intensity was necessary to avoid degeneration of the dynode voltage as a result of the high current otherwise developed (approximately 60 microamperes).

The response of the instrument in a radiation field is very rapid compared to other types of radiation detectors. The response time is determined by the microammeter movement.

Although the basic stability of the circuit is good, it was decided early in the development that a calibration source should be included. The calibration source can be visible light rather than a gamma or beta source. Work with various lights led to the conclusion that the problem of stabilizing the light source could be a very considerable one if the stability of the light was to be greater than that of the circuit itself. A happy solution, however, was found in the use of a luminous standard prepared by mixing a suitable phosphor and strontium 90 as a beta source and enclosing the result in a plastic covering. The drop in output over a period of time is very small and appears to follow directly the decay of activity of the strontium 90 which has a half-life of 25 years. A light pipe is provided from this luminous source to an aperture in the shutter surrounding the phototube so that in the calibrate position the main phosphor is isolated from the phototube and only the calibration source produces electrons at the photocathode. Since the main phosphor does not produce

any signal during calibration, it is quite possible to calibrate the instrument satisfactorily in a radiation field. Here, again, the direct response of the phototube would limit calibrating in fields of extremely high intensity.

The high-voltage battery was never intended to be a permanent power supply for the instrument. Several different power supplies were developed but the desire to have the instrument operate from standard type-D flashlight cells eventually eliminated a radio-frequency power supply which otherwise appeared promising. A miniature 500-cycle shunt vibrator was used, but operating problems including shorter than desirable life eventually led to the choice of a 60-cycle series vibrator and power supply. (See Figure 6.)

Four type-*D* flashlight cells supply 6 volts for the vibrator and primary of the power-supply transformer in series. The remaining type-*D* flashlight cell is used for the filaments of the bridge tubes.

The use of the technique called "potting" has been employed to a considerable extent in this instrument. Since the temperature rise of the parts is negligible, the use of a clear plastic for potting enables a better appearance of the potted unit and at the same time provides for visual inspection of the component. Greater heat would require the use of a filler in the plastic to increase heat conductivity.

The bridge amplifier has been potted with both tubes and the load resistors included in a plug-in unit. The base of the photomultiplier tube has been potted including the voltage-dividing resistor network. The neon-tube bank has similarly been potted as indicated. The molding of anthracene chips, which is a form of potting, has already been mentioned. (See Figure 7.)

The operation of the instrument is comparatively simple. The controls consist of the scale-selection switch which includes positions for a battery check, zero adjust, calibrate, and the four ranges; an adjustment for zero and an adjustment for calibrate. (See Figure 8.)

The instrument is turned on by the range-selection switch being set to zero position. In this position after suitable warm-up time, the zero adjustment is set so that the vacuum-tube bridge is balanced. The range-selection switch is then set to calibrate and the shunting resistor in parallel with the indicating meter is adjusted to a standard value on the meter so that the sensitivity of the entire instrument is the same as when it was factory calibrated against radiation standards. From this point the operator has but to choose the range required by the particular use to which the instrument is to be put.

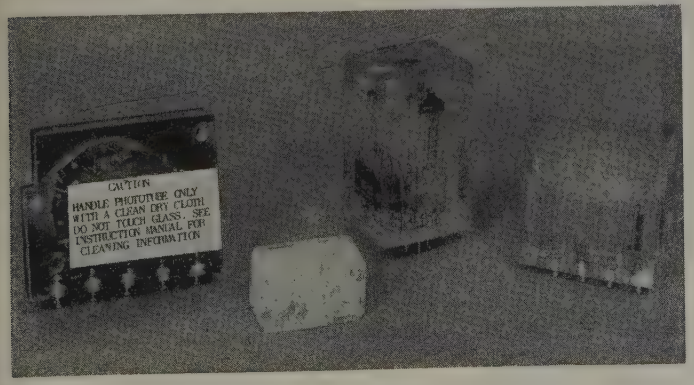


Figure 7. Potted components for the AN/PDR-18 phosphor-phototube radiation detector

Figure 8. AN/PDR-18 Radiac

The instrument is constructed to have smooth surfaces to permit easy decontamination. The use of O ring gaskets eliminates the cracks, that are common to an assembly that has external controls, and also seals the instrument preventing contaminated particles, as well as moisture, from getting inside the case.

The battery compartment is sealed separately from the main instrument compartment. The batteries are protected by a sealed cover and the compartment itself is sealed. This provision protects the instrument during the interval that it takes to change batteries.

The instrument is generally carried by means of an adjustable shoulder strap, however, it can be carried by means of the handle. The handle has an additional feature in that a momentary type switch, located for convenient operation, provides a light for dial illumination to permit using the instrument at night.

Comparative field tests to date have shown this instrument to be reliable under severe conditions of use.

SUMMARY

The development of the *AN/PDR-18*, a phototube-phosphor combination, as a reliable radiation detector has been described. This description is intended to indicate a detector which utilizes the average current from the phototube rather than pulses as from the scintillation-counter-type detector. The resulting instrument is stable, has a very fast time constant as compared to either ionization-chamber or Geiger-tube instruments, can be zeroed and calibrated in a radiation field, operates from common flashlight cells, and covers the range from approximately 0.05 to 500 roentgens per hour in four linear decades. It has an energy dependence error of less than ±15 per cent over the energy range from 0.08 to 2 million electron volts, it is rugged, watertight, and shock resistant. It is, in short, a useful portable survey instrument to military specifications for high-intensity work.

INSTITUTE ACTIVITIES

Air Transportation Featured on Program for Middle Eastern District Meeting

Three days of interesting and varied activities are in store for AIEE members who plan to attend the Middle Eastern District Meeting, October 28–30, 1952. Toledo, Ohio, glass center and leading coal port of the world, is host for this meeting. The Commodore Perry Hotel has been chosen as headquarters hotel and all technical sessions will be held there. The sessions have been carefully planned to cover a varied field of interests and the inspection trips will afford an opportunity to see a cross section of Toledo's industry.

Charles E. Ide, president of the Toledo Edison Company and Honorary Chairman, will preside at the opening session on Tuesday, October 28, at 10:00 a.m. The address will be given by Walker L. Cisler, president of the Detroit Edison Company. Mr. Cisler is also a consultant to the Army and State Department on electric power in the occupied areas.

Following the general session, a luncheon will be served in the Ballroom, officially welcoming the members as guests of the Toledo Section.

One of the features of the meeting will be the Tuesday afternoon session on "Management." This discussion should be beneficial to engineers with limited management experience or those who desire to enter the executive phase of the profession.

The Middle Eastern District Executive Committee will meet on Monday, October 27, at the headquarters hotel.

The AIEE Air Transportation Committee has selected this District meeting for its semiannual meeting. Morning and afternoon sessions will be held on all three days. There will be a special luncheon for the committee on Thursday in the French Room of the Commodore Perry Hotel and the annual business session will be held on Friday morning, October 31, at 9:00 a.m.

Students of the Middle Eastern District will hold a conference at the University of Toledo on Friday and Saturday, October 31 and November 1. The students are encouraged to attend the sessions of the District meeting and they are welcome to attend any of the inspection trips and social functions.

INSPECTION TRIPS

In addition to the four trips listed in the following, arrangements can be made for informal inspection of local utility installations. Members should contact the Inspection Trips Committee at the desk provided for these special trips.

Sun Oil Company (Wednesday, October 29, 1:30 p.m.). This refinery is the largest in the Toledo area. Each day it can produce sufficient gasoline to run an average automobile for 1,900 years. The world's tallest refinery unit and the first of its kind, a new catalytic cracking tower is located in the Toledo plant.

Willys Overland Motors, Inc. (Wednesday, October 29, 1:30 p.m.). The home of the "jeep," here members can view the assembly lines as well as the giant press and forging operations. A guided tour will be of much interest to all electrical engineers as the military jeep is complete with electric components, some designed specifically for underwater operation.

Chesapeake and Ohio Coal and Ore Docks (Thursday, October 30, 1:30 p.m.). This is one of two docks that give Toledo its position as the leading transshipper of soft coal in the world. The Chesapeake and Ohio coal handling equipment can empty 4,500 coal cars per day and has slips to accommodate 16 lake freighters at one time. The huge car dumpers, ore unloaders, and car pushers afford an opportunity to see the electric equipment and devices at work.

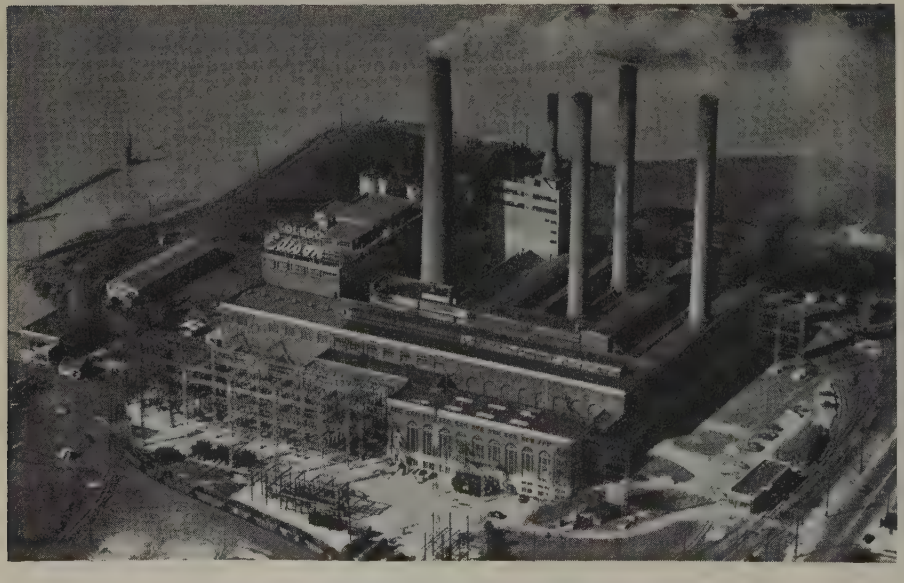
Toledo Scale Company (Thursday, October 30, 1:30 p.m.). This modern plant is devoted to the manufacture of automatic retail and industrial scales and special testing devices. Here weighing devices are developed and manufactured which incorporate many electric and electronic circuit elements in their construction.

ENTERTAINMENT

An interesting program has been arranged for the entertainment of the members and guests in attendance at the Middle Eastern District Meeting.

On Tuesday, October 28, a smoker will be held in the Crystal Room of the Commodore Perry Hotel at 7:30 p.m. This event will provide an opportunity for members to be together for an evening of relaxation and fun. There will be music, refreshments, snacks, and a full hour show.

The banquet on Wednesday evening, October 29, at 7:00 p.m., in the Crystal Room will wind up the social part of the meeting for the members and their ladies.



The Acme Station of the Toledo Edison Company

Future AIEE Meetings

Fall General Meeting (*page 943*)
Jung Hotel, New Orleans, La.
October 13–17, 1952

Middle Eastern District Meeting
Commodore Perry Hotel, Toledo, Ohio
October 28–30, 1952
(*Final date for submitting papers—closed*)

AIEE Conference on Machine Tools
Ten Eyck Hotel, Albany, N. Y.
October 29–31, 1952

AIEE Conference on Textiles
North Carolina State College, Raleigh, N. C.
November 6–7, 1952

AIEE Special Technical Conference on Electrically Operated Recording and Controlling Instruments
Benjamin Franklin Hotel, Philadelphia, Pa.
November 17–18, 1952
(*Final date for submitting papers—closed*)

Conference on Electronic Instrumentation and Nucleonics in Medicine
Hotel New Yorker, New York, N. Y.
November 24–25, 1952

Joint AIEE-IRE-ACM Conference on Electronic Computers
Park Sheraton Hotel, New York, N. Y.
December 10–12, 1952

AIEE-IRE-NBS Conference on High-Frequency Measurements
Statler Hotel, Washington, D. C.
January 14–16, 1953

Winter General Meeting
Statler Hotel, New York, N. Y.
January 19–23, 1953
(*Final date for submitting papers—October 21*)

Grove Patterson, editor-in-chief of the *Toledo Blade*, world traveler and nationally known and highly respected newspaperman, will be the speaker. Music will be furnished and each lady will receive a special attractive favor.

LADIES' ENTERTAINMENT

The Ladies' Entertainment Committee under the chairmanship of Mrs. W. E. Boruh has planned an interesting program of events and trips.

On Tuesday, October 28, from 2:00 p.m. to 4:00 p.m., a get-acquainted tea will be held at the Commodore Perry Hotel, and at 7:00 p.m. Tuesday evening, a dinner and card party will be held at the Toledo Woman's Club.

At 10:30 a.m. on Wednesday an interesting trip will be made through the nationally known Grace E. Smith cafeteria with luncheon being served at 11:30 a.m. At 2:30 p.m. the same day, arrangements have been made for a most unusual and educational inspection trip through the Libbey Glass Division of the Owens Illinois Glass Company, manufacturers of Safe Edge glassware and Libbey hostess sets.

Wednesday evening at 6:30 p.m. the ladies will join the men at the banquet to be held in the Commodore Perry Hotel. Thursday will be free for the ladies to visit Toledo's fine shopping district within walking distance of the hotel. The ladies are also invited to attend the opening day luncheon on Tuesday.

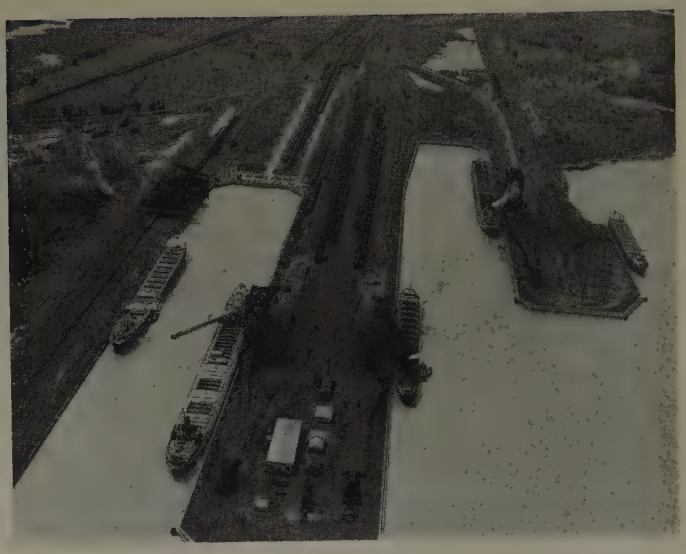
The French Room in the hotel has been designated as headquarters for the ladies' convenience during their stay in Toledo. Members of the Ladies Committee will be on hand continually to help ladies arrange tours other than those listed and to get acquainted with each other.

REGISTRATION AND RESERVATIONS

Advance registration is requested by returning the advance registration card, properly filled out. Arrangements have been made to expedite the registration of those who send in the cards promptly. The registration fee, payable at the meeting, is $2.00 for members and $3.00 for nonmembers. No fee is required of enrolled students and immediate families of members. Reservations for luncheons, social functions, and inspection trips should be made at the ticket sale desk.

Reservations should be made directly with the hotel desired. Rooms with bath are available at the following minimum rates and up.

	Single	Double	Twin Beds
Commodore Perry	4.50	7.00	9.50
Secor	4.00	6.50	8.00
Fort Meigs	4.00	6.00	8.75



Chesapeake and Ohio coal and ore docks will be inspected during the Middle Eastern District Meeting in Toledo

COMMITTEES

General Chairman for the meeting is M. W. Keck, Honorary Chairman is C. E. Ide, and Roy Stott is Secretary-Treasurer. Host Section for the meeting will be the AIEE Toledo Section with L. H. Fox, Chairman; J. B. Cloer, Vice-Chairman; and S. J. Tombaugh, Secretary. The committees handling arrangements for the meeting are

Scheduling: L. E. Smith (Chairman), Richard May

Technical Program: J. W. Cofer (Chairman), J. R. Bryan A. Hoefle, J. H. Hunt, H. E. Koler, Paul Thornbury

Inspection Trips: W. H. Schwalbert (Chairman), C. E. Flahie, C. L. Keller, T. J. Kozak

Registration and Finance: D. L. Rexford (Chairman), R. W. Elder, W. U. Gorton, C. F. Iffland, B. W. Wallace

Entertainment and Publicity: W. E. Boruh (Chairman), W. L. Beat, J. B. Cloer, H. A. Grasser, F. C. Helwig, R. L. Manor

Ladies' Program: Mrs. W. E. Boruh (Chairman), Mrs. W. M. Campbell, Mrs. A. Hoefle, Mrs. M. W. Keck, Mrs. W. H. Schwalbert, Mrs. B. W. Wallace

Student Activities: Tsute Yang

Tentative Technical Program

Middle Eastern District Meeting, Toledo, October 28-30

Tuesday, October 28

10:00 a.m. General Session

Charles E. Ide, presiding

Address: "Management Looks Ahead in the Electric Power Industry." W. L. Cisler, The Detroit Edison Company

Presentation of District Prize Paper Awards. J. C. Strasbourger, Vice-President, AIEE

12:30 p.m. Luncheon, Ballroom

2:00 p.m. Management

C. J. Beller, presiding

DP. Management Development.** *L. A. Russ*, Westinghouse Electric Corporation

DP. Human Relations in the Management Team.** *E. C. Stone*, University of Pittsburgh

2:00 p.m. Air Transportation

J. W. Allen, presiding

DP. Operation Problems of Air Turbines for Accessory Drives.** *T. E. Abraham*, Douglas Aircraft Company, Inc.

DP. A New Hydraulic Constant-Speed Drive.** *R. E. Thorn, E. E. Lewis*, General Electric Company

52-311. Automatic Synchronizing for Aircraft Alternators. *F. B. McCarty, G. W. Hills*, Convair

DP. The Maintenance of Electric Equipment on Modern Airplanes.** *A. J. Mustard*, Eastern Airlines

2:00 p.m. Meeting of the Administrative Subcommittee, Rotating Machinery Committee

7:30 p.m. Smoker, Crystal Room

Wednesday, October 29

9:30 a.m. Feedback Control Systems

F. E. Crever, presiding

DP. Drag-Cup A-C Tachometer With Constant-Current Excitation.** *R. H. Frazier*, Massachusetts Institute of Technology

52-313. Stability Limits for Third-Order Servomechanisms. *T. J. Higgins, J. G. Levinthal*, University of Wisconsin

52-199. The Use of Nonlinear Feedback to Improve the Transient Response of a Servomechanism. *J. B. Lewis*, University of Tennessee. Presentation by title only for discussion

52-344. Piecewise Linear Servomechanisms. *J. W. Schwartz*, Cornell University. Presentation by title only for discussion

52-314. An Approximate Transfer Function for the Analysis and Design of Pulsed Servos. *R. G. Brown, G. J. Murphy*, General Motors Corporation

9:30 a.m. Rotating Machinery

S. F. Henderson, presiding

52-315. A Graphical Method for Determining the Impedance of Multiple-Cage Conductors. *S. S. L. Chang*, Robbins and Myers, Inc.

52-316–ACO.* Performance Calculation of Double-Cage Induction Motors. *S. S. L. Chang, C. H. Crouse*, Robbins and Myers, Inc.

52-317. A Contribution to the Theory of the Double-Cage Induction Motor. *J. F. H. Douglas*, Marquette University

52-318. Double and Triple Squirrel Cages for Polyphase Induction Motors. *P. L. Alger, J. H. Wray*, General Electric Company

* **ACO:** Advance copies only available; not intended for publication in *Transactions*.

** **DP:** District paper; no advance copies are available; not intended for publication in *Transactions*.

9:30 a.m. Relaying

M. Robison, presiding

DP. Phase Comparison Carrier Relaying for 3-Terminal Lines.** *H. W. Lensner*, Westinghouse Electric Corporation

DP. Standardization of System Relaying.** *D. B. Brandt*, General Electric Company

DP. Typical Utility Microwave Applications.** *D. F. Burnside*, Westinghouse Electric Corporation

9:30 a.m. Air Transportation

S. H. Hanville, presiding

52-319–ACO.* Characteristics of Aircraft A-C Generators. *L. J. Stratton, L. W. Matsch*, Illinois Institute of Technology

DP. Effects of Aircraft A-C Generator Characteristics on System Performance.** *K. W. Carlson*, General Electric Company

DP. Power Equalizer Systems for Aircraft Alternators.** *J. A. Granath, A. K. Hawkes*, Illinois Institute of Technology

DP. Reactive Load Division of Parallel A-C Generators in Aircraft Electric Systems.** *E. S. Sherrard*, Naval Research Laboratories

52-322. Impedance Data for 400-Cycle Aircraft Distribution Systems. *D. W. Exner, G. H. Singer, Jr.*, Boeing Airplane Company. Presentation by title only for discussion

52-323. Continuous Current and Temperature Rise in Bundled Cables for Aircraft. *Milton Schach, R. E. Kidwell, Jr.*, Naval Research Laboratories. Presentation by title only for discussion

1:30 p.m. Inspection Trip, Sun Oil Company

1:30 p.m. Inspection Trip, Willys Overland Motors, Inc.

2:00 p.m. System Engineering

A. A. Johnson, presiding

DP. Expected National Load Growth and Its Effect on Utility Expansion.** *A. A. Johnson*, Westinghouse Electric Corporation

DP. A New-Design 60-Cycle A-C Network Analyzer.** *J. L. Davidson*, Long Island Lighting Company; *R. E. Koll*, System Analyzer Corporation

DP. Aluminum for Conductors and Electric Equipment.** *R. R. Cope*, Aluminum Company of America

DP. Commodity and Power Requirements.** *C. R. Beardsley*, Defense Electric Power Administration

2:00 p.m. Rotating Machinery

T. C. Lloyd, presiding

52-325. Defining the Equivalent Circuit of the Double-Cage Motor. *Paul Jacobs*, Westinghouse Electric Corporation

52-326. A Design Method for Double-Squirrel-Cage Induction Motors. *J. Goodman*, Allis-Chalmers Manufacturing Company

52-327. A Design Method for Double-Squirrel-Cage Induction Motors. *C. H. Lee*, Reliance Electric and Engineering Company

DP. Design Description, Test Results, and Comparison of Calculated Characteristics of Sample Double-Cage Motors.** *J. J. Courtin*, Westinghouse Electric Corporation

2:00 p.m. Air Transportation

B. O. Austin, presiding

DP. A System of Boosting Direct Voltage for Special Aircraft Applications.** *J. A. Hastings, E. L. Foster*, Lockheed Aircraft Corporation

52-328. Electrostatic Oscillation in Sensitive Contact Mechanisms. *T. R. Stuelpnagel*, Hughes Aircraft Company. Presentation by title only for discussion

52-329. Consideration of Off-On-Modulated Reversing Clutch Servo Systems. *T. R. Stuelpnagel, J. P. Dallas*, Hughes Aircraft Company

DP. Development of Static Regulators for Aircraft A-C Generators.** *D. L. Plette, H. H. Britten*, General Electric Company

52-330. Stabilizing Elements in Aircraft D-C Systems. *D. G. Scorgie, D. H. Schaefer*, Naval Research Laboratory

7:00 p.m. Banquet, Crystal Room

Charles E. Ide, presiding
Address: Grove Patterson, Editor-in-Chief of *The Toledo Blade*

Thursday, October 30

9:30 a.m. Industrial Control

J. A. Cortelli, presiding

DP. Importance and Co-ordination of Electric Controls and Power to the Refinery Process.** *M. K. Dubbs, C. H. Johnson*, Sun Oil Company

DP. Electrical Interlocking of Automatic Industrial Equipment.** *R. O. Bradley*, Toledo Scale Company

DP. Quick Stopping of Rubber Mill Motors.** *J. F. Sellers, A. Halter*, Allis-Chalmers Manufacturing Company; *Blake Wheeler*, Cutler Hammer, Inc.

9:30 a.m. System Engineering

H. H. Kerr, presiding

DP. Economic Effects of Conductor Size on Transmission-Line Loadings.** *R. M. Butler, L. E. Saline, H. J. Fiedler*, General Electric Company

52-331–ACO.* Power Supply to Critical Loads. *S. G. Farace, P. W. Crosby*, Philadelphia Electric Company

DP. Power Supply to Critical Loads in the Glass Industry.** *N. W. James*, Libbey-Owens-Ford Glass Company

9:30 a.m. Air Transportation

Ray D. Jones, presiding

DP. Regulated Transformer Rectifiers.** *G. B. Farnsworth*, General Electric Company

DP. Study of a Transformerless Rectified 120-Volt D-C Aircraft Electric System.** *J. P. Dallas, C. A. Reising, Jr.*, Hughes Aircraft Company

DP. Economic Factors for Aircraft Electric Power Systems.** *R. M. Bergslien, L. J. Stratton, H. J. Finison*, Armour Research Foundation

DP. Co-ordination of Circuit Protection Devices With Cables.** *Rudolf Steiner*, USNADC

52-332. Feeder Fault Protection for D-C Aircraft Generators. *W. W. Davis*, Boeing Airplane Company. Presentation by title only for discussion

52-333. Arc Interruption Phenomena in a Magnetic Field at Altitude. *J. P. Dallas*, Los Angeles, Calif. Presentation by title only for discussion

DP. Current Transformer Differential Protection for Aircraft D-C Systems.** *C. A. Brown*, General Electric Company

12:30 p.m. Air Transportation Committee Luncheon, French Room

1:30 p.m. Inspection Trip, Chesapeake and Ohio Coal and Ore Loading Docks

1:30 p.m. Inspection Trip, Toledo Scale Company

2:00 p.m. Electrical Applications in Glass Industry

James E. Arberry, presiding

DP. Comparison of Induction Regulators and Saturable Reactors for Electric Melting of Glass.** *C. R. Olson*, Westinghouse Electric Corporation

DP. Co-ordinated Sectional Drives in the Manufacture of "Fiberglas."** *N. A. Dragics*, Owens-Corning Fiberglas Corporation

52-320. Electric Power Applications in the Glass Industry. *E. A. E. Rich*, General Electric Company

DP. Electric Glass Welding.** *M. R. Shaw*, Corning Glass Works

2:00 p.m. Power Plants and Equipment

L. R. Gaty, presiding

DP. Electrical Features of Eastlake Generating Station.** *C. F. Paulus*, Cleveland Electric Illuminating Company

DP. A Study for the Selection of a Station Power 1-Line Diagram.** *L. E. Smith*, Toledo Edison Company

52-334–ACO.* A Fluid Network Reduction Method for Accurate Representation of the Nonlinear Characteristics. *W. T. Brown, R. A. Markel*, Philadelphia Electric Company

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES of papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in the bimonthly publications and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

2:00 p.m. Rotating Machinery

C. G. Veinott, presiding

DP. Magnetic Noise in Salient-Pole Synchronous Machines.** *W. L. Ringland*, Allis-Chalmers Manufacturing Company

DP. The Figure of Merit of D-C Rotating Power Amplifiers.** *J. T. Carleton*, Westinghouse Electric Corporation

DP. Analogue Comparator as a Tool in Motor Application.** *J. L. Fuller, A. P. DiVincenze*, Reliance Electric and Engineering Corporation

DP. Automatic Speed Controls for the A-C Brush-Shifting Commutator Motor.** *V. J. Picozzi*, General Electric Company

52-343–ACO.* Apparatus for Determination of Induction Motor Torque. *K. M. Chirgwin*, English Electric Company of Canada, Ltd.

2:00 p.m. Air Transportation

R. L. Olson, presiding

52-335. A Review of the Factors Affecting the Temperature of Air-borne Electric and Electronic Equipment. *L. J. Lyons*, Northrop Aircraft Inc.

52-336. Altitude Chamber Requirements for Evaluating Blast-Cooled Aircraft Generators. *D. H. Scott*, Naval Research Laboratory

52-337–ACO.* Thermodynamic and Aerodynamic Evaluation of Aircraft Generator Installations. *D. Friedman, J. M. Marzolf*, Naval Research Laboratory

52-338. Improving the Dynamic Response of Airplanes by Means of Electric Equipment. *W. R. Monroe*, North American Aviation, Inc.

Friday, October 31

9:00 a.m. Annual Business Meeting of Committee on Air Transportation

12:00 noon. Air Transportation Committee Luncheon

Tentative Technical Program Announced for Fall General Meeting in New Orleans

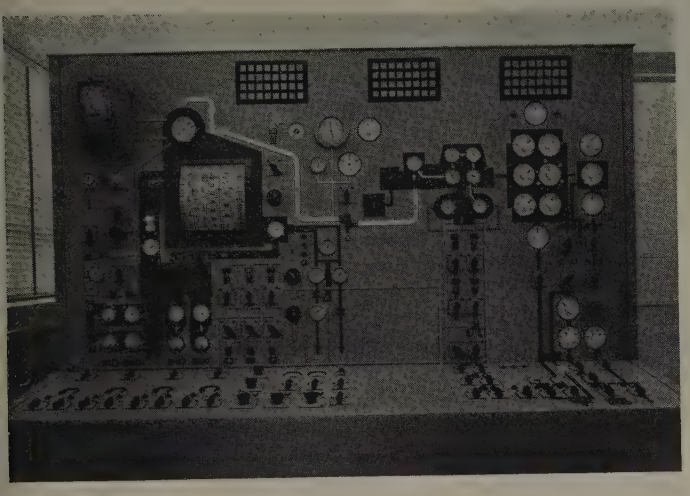
A full week of stimulating technical sessions, interest-packed inspection trips, and relaxing entertainment awaits the AIEE membership at the Fall General Meeting in New Orleans, La., October 13–17, 1952. Both the technical program and the inspection trips were planned with the wide interests of the membership in mind. Headquarters for the meeting will be at the Hotel Jung.

The Honorable Robert F. Kennon, Governor of the State of Louisiana, will deliver the keynote address at the general session on Monday, October 13, at 10:00 a.m. Insulated Conductors, Power Generation, Education, Carrier Current, Magnetic Amplifiers, System Engineering, Rotating Machinery, Relays, Management, Safety, Feedback Control, The Chemical and Petroleum Industries in the South, Transmission and Distribution, Radio Communications, Communication Switching, Cathodic Protection, Wire Communication, and General Industry Applications are the subjects scheduled for discussion at the technical sessions.

Inspection trips morning and afternoon will afford a cross-sectional view of New Orleans' varied industries with a large number of scheduled trips from which to choose. Many of these trips will feature the latest developments in plant design, machine tools, and power generation. One of the most unusual trips will be the inspection of the Sewerage and Water Board facilities for the City of New Orleans.

The members of the 1952 Fall General Meeting Committee are James M. Todd, Chairman; Charles P. Knost, B. P. Babin, B. E. Segall, Vice-Chairmen; E. I. Blanchard, Secretary-Treasurer; E. S. Lammers, Jr., Vice-President District 4; H. E. Pritchard, Jr., J. Robert Rombach, Jr., Members-at-Large; F. E. Johnson, Technical Programs; H. C. Swan, Inspection Trips; James C. Ryan, Publicity; B. H. Bell, Entertainment; H. A. Schaeffer, Jr., Hotels and Registration; W. D. Stroud, Finance; W. J. Drawe, Transportation; M. J. Cade, Printing; W. S. Leake, Sports; L. T. Frantz, Reception; D. H. Vliet, Students.

For a schedule of hotel rates, and for more complete details of the social events and inspection trips planned for the meeting, see *Electrical Engineering* for September, pages 813–14 and 816.



Interior of the Nine Mile Point Generating Station of the Louisiana Power and Light Company, which is scheduled for inspection during the Fall General Meeting in New Orleans

Tentative Technical Program

Fall General Meeting, New Orleans, La., October 13-17

Monday, October 13

10:00 a.m. General Session

Address of welcome. Governor Robert F. Kennon

"Oil Progress in Louisiana." Henry J. Voorhies, vice-president and general manager, Standard Oil Company, Louisiana Division

Address. AIEE President D. A. Quarles

2:00 p.m. Insulated Conductors

52-281. Grounding and Corrosion Protection on Underground Electric Power Cable Sheaths and Oil- or Gas-Filled Pipe Lines. *R. J. Kuhn*, Consulting Engineer

52-282. The Use of Trays and Troughs for Supporting Control and Power Cables in Electrical Installations. *F. S. Benson*, Pacific Gas and Electric Company

CP. Grounding Coaxial and Shielded Cable.** *Michael Manzi, J. H. Marsman*, Sperry Gyroscope Company; *Morris Brenner*, Burndy Engineering Company

CP. Some Operating Features of the Electric System of the Sewerage and Water Board of New Orleans, La.** *L. T. Frantz*, New Orleans, La.

2:00 p.m. Power Generation

52-283. Surge Phenomena in Large Unit-Connected Steam Turbine-Generators. *P. A. Abetti, I. B. Johnson, A. J. Schultz*, General Electric Company

52-284. Field Investigation on the Surge Performance of a Large Unit-Connected Steam Turbine-Generator. *H. R. Armstrong*, Detroit Edison Company; *S. B. Howard, I. B. Johnson*, General Electric Company

* **ACO:** Advance copies only available; not intended for publication in *Transactions*.

** **CP:** Conference paper; no advance copies are available; not intended for publication in *Transactions*.

52-285. Experience With Television for Direct Viewing of Furnaces. *L. M. Exley*, Long Island Lighting Company

52-287–ACO.* Television in Industry. *G. H. Wilson*, Diamond Power Specialty Corporation

CP. Television for Monitoring Stack Emission.** *E. R. Thomas*, Consolidated Edison Company; *W. L. Norvel*

Tuesday, October 14

9:30 a.m. Insulated Conductors

CP. A Historical Review of Aluminum Applications in Industrial Cables.** *H. W. Biskeborn*, Kaiser Aluminum and Chemical Corporation

CP. Insulated Aluminum Conductors.** *E. G. Sturdevant*, United States Rubber Company

CP. Significant Characteristics of Insulated Aluminum Cables.** *E. E. McIlveen*, The Okonite Company

CP. Current-Carrying Capacities of a Few Sizes of Aluminum Conductors.** *C. W. Zimmerer*, Underwriters' Laboratories, Inc.

CP. Fundamental Problems Encountered in Aluminum Connections.** *C. P. Xenis*, Consolidated Edison Company, Inc.

9:30 a.m. Power Generation

52-286. Auxiliary Power System for Steam-Electric Generating Stations. *A. G. Mellor, R. A. Schmidt, Jr.*, General Electric Company

52-274. Considerations in the Design of the Station Auxiliary System at the Encina Generating Station. *T. H. Jacobsen*, Pioneer Service and Engineering Company; *J. F. Sinnott*, San Diego Gas and Electric Company

52-279–ACO.* Power Supply for Powerhouse Auxiliaries. *R. W. Ferguson*, Westinghouse Electric Corporation

CP. Power Supply System for Station Auxiliaries.** *M. G. Lewis, S. H. Wright*, Bechtel Corporation

9:30 a.m. Carrier Current

52-275. Application of Line Traps to Power-Line Carrier Systems. *J. D. Moynihan*, Westinghouse Electric Corporation

52-288. The Relation Between Bandwidth and Speed of Response in Power System Control Channels. *J. S. Smith*, General Electric Company

52-280. Radio-Frequency Hybrids Used for Paralleling Terminal Equipment for Closely Spaced Carrier-Current Channels. *R. W. Beckwith*, General Electric Company

CP. A New Line of Frequency-Modulated Carrier Communication Equipment.** *F. B. Gunter*, Westinghouse Electric Corporation

2:00 p.m. Insulated Conductors

CP. Insulated Aluminum Cables in Industrial and Utility Applications.** *E. E. McIlveen*, The Okonite Company

CP. Forty Years' Experience With Aluminum Bus at Niagara Falls, N. Y.** *William Boyd*, Aluminum Company of America

CP. Test of Fittings on Insulated Aluminum Cable.** *J. Tompkins, E. Lanetot*, Aluminum Company of America

CP. The Use of Aluminum Conductors in Industrial Electric Power Systems.** *A. L. Nelson*, Consulting Engineer

2:00 p.m. Power Generation

52-291. Reactance Relays Discriminate Between

Aerial view of New Orleans showing Canal Street with the Mississippi River in the foreground

Load Transfer Currents and Fault Currents on 2,300-Volt Station Service Generator Bus. *G. B. Dodds, W. E. Marter*, Duquesne Light Company

52-289–ACO.* Operating Experiences With Power Plant Auxiliary Systems. *H. F. Tevlin, L. H. Romzick*, Detroit Edison Company

52-290–ACO.* Application Features of Major Auxiliary-Drive Motors in Electric Generating Stations. *J. H. Ashby, A. E. Beardmore, R. C. Goodwin, H. G. Schiff*, General Electric Company

CP. Station Auxiliary Power Practices on Extended Hydro-Steam System.** *H. C. Austin*, Southern California Edison Company

2:00 p.m. Management

CP. Incentives to Accomplish Greater Productivity.** *R. J. Stockham*, Stockham Valves and Fittings

CP. Stepping Stones to Good Industrial Relations.** *J. S. Gracy*, Florida Power Corporation

Wednesday, October 15

9:30 p.m. Education

CP. Conference on the Manpower Shortage in Power Education.** *J. D. Ryder*, University of Illinois

CP. Opportunities for Engineers in the Electrical Utility Industry.** *R. F. Danner*, Oklahoma Gas and Electric Company

CP. The Utilities and Power Education.** *G. S. Dinwoodie*, New Orleans Public Service, Inc.

CP. The Equipment Manufacturer and Power Education.** *H. N. Muller*, Westinghouse Electric Corporation

9:30 a.m. Safety

52-292. Improved Pole-Top Resuscitation. *A. S. Gordon, Charles Frye, M. S. Sadove*, University of Illinois

CP. Safety Regulations and How They Affect the Electrical Industry.** *L. D. Price*, National Electrical Manufacturers Association

CP. The Role of the Supervisor in Safety Work.** *W. H. Seynard*, Louisiana Power and Light Company

9:30 a.m. Feedback Control Systems

52-277. Stabilization of a Servomechanism Subject to Large Amplitude Oscillation. *E. S. Sherrard*, General Electric Company

52-272. Lead Networks Utilizing Saturable Core Memory. *D. G. Scorgie*, Naval Research Laboratory

52-297. Synthesis of Feedback Control System by Phase-Angle Loci. *Yaohan Chu*, Cambridge, Mass.

52-298. Vacuum Tube Techniques Applied to a Hydraulic Amplifier. *J. A. Baring*, Askania Regulator Company

52-211. Signal Component Control. *D. J. Gimpel, J. F. Calvert*, Northwestern University. Presentation by title only for discussion

52-200. Feedback Control Systems With Dead-Time Lag or Distributed Lag by Root-Locus Method. *Yaohan Chu*, Cambridge, Mass. Presentation by title only for discussion

52-309. Ferroelectric Materials as Storage Elements for Digital Computers and Switching Systems. *J. R. Anderson*, Bell Telephone Laboratories, Inc. Presentation by title only for discussion

52-310. Design Improvements and Operating Experience With 10-Kc Network Analyzers. *J. D. Ryder*, University of Illinois; *W. B. Boast*, Iowa State College. Presentation by title only for discussion

2:00 p.m. Magnetic Amplifiers

52-271. Magnetic Amplifiers of the Self-Balance Potentiometer Type. *W. A. Geyger*, Naval Ordnance Laboratory

52-293. Single-Core Magnetic Amplifier as a Computer Element. *R. A. Ramey*, Naval Research Laboratory

CP. Ferroresonant Circuits for Digital Computers.** *C. F. Spitzer*, General Electric Company

CP. Dynamic Hysteresis Loops of Several Core Materials Employed in Magnetic Amplifiers.** *H. W. Lord*, General Electric Company

2:00 p.m. System Engineering

CP. Load Forecasting—A Method Based on Economic Factors.** *F. W. Brooks*, Cleveland Electric Illuminating Company

CP. Forecasting the Demand for Electricity.** *R. G. Hooke*, Public Service Electric and Gas Company

CP. Load Forecasting and Utilization of Forecasts.** *Carl Kist*, Department of Water and Power, Los Angeles

CP. A Suggested Approach to Load Forecasting.** *C. L. McNeese*, Houston Lighting and Power Company

2:00 p.m. Rotating Machinery

CP. Advantages of Operating Turbogenerators at Increased Hydrogen Pressures.** *J. W. Batchelor*, Westinghouse Electric Corporation

CP. Operating Experience With Supercharged Rotor Cooling.** *L. T. Rosenberg*, Allis-Chalmers Manufacturing Company

CP. Thermalastic Insulation for High-Voltage Water-Wheel Generators.** *W. Schneider*, Westinghouse Electric Corporation

CP. Starting Torque of a Single-Phase Single-Winding Motor.** *M. S. Pendergast*, Southwestern Louisiana Institute

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES of papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in the bimonthly publications and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

Thursday, October 16

9:30 a.m. Relays

52-294. Ground Relay Polarization. *J. L. Blackburn*, Westinghouse Electric Corporation

CP. More About Setting Industrial Relays.** *F. P. Brightman*, General Electric Company

CP. Protection of Generators Against Unbalanced Current.** *J. E. Barkle, W. E. Glassburn*, Westinghouse Electric Corporation

CP. Improved Sensitivity of Relay for Primary Networks.** *C. A. Mathews*, General Electric Company

9:30 a.m. The Chemical Industry in the South

CP. Aspects of Delivering Constant Current to an Electrolytic Cell Line.** *E. H. Coxe*, Ethyl Corporation

CP. Washing High-Voltage Equipment at the Ethyl Corporation.** *W. G. Whitley*, Ethyl Corporation

CP. Service Engineering Organization and Problems Peculiar to the Chemical Industry.** *W. C. Dreyer*, Westinghouse Electric Corporation

CP. Lighting of a Southern Chemical Plant.** *J. H. Snow*, The Dow Chemical Company

CP. Alcoa Point Comfort Power Installation.** *Howard Keefer*, Aluminum Company of America

9:30 a.m. Switchgear

52-268. Selecting Station-Type Switchgear Equipment for Large Generating Stations. *K. T. Ashdown*, General Electric Company

52-295. Application of Aluminum Channel Conductors for Station Bus. *E. J. Casey, N. Swerdlow*, General Electric Company

52-269. A New Heavy-Duty 3-Phase Oil Circuit Reclosure. *A. Van Ryan*, Kyle Products Plant

52-296. The Effect of Repeated Faults on Fuse Characteristics. *R. E. Riebs*, Line Material Company

2:00 p.m. Transmission and Distribution

CP. Trends in High-Voltage Transmission.** *S. B. Griscom, A. A. Johnson*, Westinghouse Electric Corporation

52-278. Insulation Co-ordination. *C. F. Wagner*,

. L. Witzke, E. Beck, W. L. Teague, Westinghouse Electric Corporation

2-299. Power Losses in Interconnected Transmission Networks. *H. W. Hale*, Purdue University

2-273. Generalized Hunting Equations of Power Systems. *W. G. Heffron, Jr., G. M. Rosenberry, F. S. Cothe*, General Electric Company

2-270. Operation of Synchronous Condensers on the Southern California Edison System. *C. R. Canady, J. H. Drake*, Southern California Edison Company. Presentation by title only for discussion

2:00 p.m. The Petroleum Industry in the South

CP. Operating Experience on the World's Largest Products Line.** *R. S. Cannon, F. Armstrong*, Plantation Pipe Line Company

CP. Pipe-Line Stations by Supervisory Control.** *Clyde Hepler*, Pan American Pipe Line Company

CP. The Electric System Reliability Required in Petroleum Refining Operations.** *E. R. Felton*, Esso Standard Oil Company

CP. By-product Power for Topping Turbine.** *J. B. Glasby*, Atlantic Refining Company

2:00 p.m. Radio Communications

CP. Radio Aids to Navigation.** *L. E. Brunner*, United States Coast Guard

CP. Radio Activities of the Air Navigation Development Board.** *W. M. Young*

52-300. Radio Interference Control. *C. F. Maylott*, Bendix Aviation Corporation

CP. Pulse-Time Modulation Microwave Applications in the Pipe-Line and Utilities Field.** *R. G. Maddox*, Federal Telephone and Radio Corporation

Friday, October 17

9:30 a.m. Transmission and Distribution

52-301. Developments and Experience With Series Capacitors in Sweden. *G. Jancke, K. F. Akerstrom*, Swedish State Power Board. Presentation by title only for discussion

52-302. A Simplified Sag Tension Method for Steel-Reinforced Aluminum Cable. *C. A. Jordan*, General Cable Corporation

52-303. Determination of Resistance to Ground of Grounding Grids. *A. J. McCrocklin*, University of Texas; *C. W. Wendlandt*, Consolidated Vultee Aircraft Corporation

CP. Resistance of Exposed Clamp-Type Connectors for Steel-Reinforced Aluminum Cable Conductor Over a 5-Year Period.** *W. F. Bonwitt*, Burndy Engineering Company, Inc.

CP. Unbalance of Untransposed Overhead Lines.** *E. T. B. Gross, Ray Berman, C. T. Wint*, Illinois Institute of Technology

9:30 a.m. Communication Switching Systems

CP. Development of the Wire Contact Relay.** *R. E. Markle*, International Business Machines Corporation

52-304. A New General-Purpose Relay for Telephone Switching Systems. *A. C. Keller*, Bell Telephone Laboratories

52-276-ACO.* Selective Control Switching System for Radio-Telegraph Transmission. *J. M. Robinson*, North Electric Manufacturing Company

CP. Telephone System Applications of Recorded Machine Announcements.** *W. Bennett*, Bell Telephone Laboratories, Inc.

9:30 a.m. Cathodic Protection

52-305. Measurement of Cathodic Protection Currents From Sacrificial Anodes. *H. N. Hayward, R. M. Wainwright*, University of Illinois

52-306. The Use of Graphite Anodes for Cathodic Protection of the Bottoms of Inactivated Ships. *J. P. Oliver*, National Carbon Company

CP. Cathodic Protection of Refinery Equipment.** *Derk Holsteyn*, Shell Oil Company

CP. Cathodic Protection of Electric Substations and Power Plants.**

2:00 p.m. Wire Communications System

52-307. Type O Carrier Telephone. *J. A. Coy, E. K. Van Tassel*, Bell Telephone Laboratories, Inc.

CP. Transposition Designs for Type O Carrier Systems.** *E. Rentrop, L. Hochgraf*, Bell Telephone Laboratories, Inc.

CP. Applications of the Type O Carrier System.** *J. Dechovitz*, Southern Bell Telephone and Telegraph Company

CP. The 45A Carrier System.** *R. S. Caruthers*, Lenkurt Company, Inc.

2:00 p.m. General Industry Applications

CP. Regulating Systems for Industrial Applications.** *V. B. Baker, W. R. Harris*, Westinghouse Electric Corporation

52-308. Voltage Rating Versus Horsepower of Synchronous and Induction Motors. *C. E. Miller*, General Electric Company

CP. A Modern Textile Distribution System.** *N. Stadtfeld, J. R. Potter*, Westinghouse Electric Corporation

52-339. Load Characteristics of Five All-Electric Residences Using the Heat Pump for Year-Round Air Conditioning. *Philip Sporn, E. R. Ambrose*, American Gas and Electric Service Corporation. Presentation by title only

52-340. Residential Heat Pump Experiments in Philadelphia—Suggested Possibilities for Practical Applications. *Constantine Bary*, Philadelphia Electric Company. Presentation by title only

52-341. Residential Heat Pump Experiments in Philadelphia—Earth as a Heat Source. *A. H. Kidder, J. H. Neher*, Philadelphia Electric Company. Presentation by title only

52-342. Residential Heat Pump Experiments in Philadelphia—Installation and Operating Experience. *J. H. Harlow, G. E. Klapper*, Philadelphia Electric Company. Presentation by title only

Pacific General Meeting Program Treats Problems of the Southwest

With the AIEE Arizona Section as host, the 1952 Pacific General Meeting was held in Phoenix, Ariz., in the Westward Ho Hotel, August 19–22, 1952. A total of 17 sessions was held during the 4 days including an opening general session and a Student technical session. The Board of Directors held an important all-day meeting as did the Pacific District Executive Committee. Special events were arranged for the ladies and social functions were held each evening. Sport shirts without ties were the order of the day and the air of informality was conducive to a free and frank discussion of important topics. Over 500 members and guests were in attendance.

GENERAL SESSION

An address, "Industrial Growth in Arizona," by H. B. Sargent, President, Arizona Public Service Company, served as an appropriate introduction to the meeting. The extremely rapid rate of growth of the state in comparison to the rate of growth in the United States in the last decade and particularly in the last 5 years was clearly brought out. In the past decade, there has been a 10 per cent increase in the population as compared to a 5 per cent increase for the United States as a whole. Values of mineral products have increased nearly three times that of 1940 and have not yet reached the peak production. In respect to agricultural production, Mr. Sargent pointed out that there is a sharp difference of opinion as to which states are entitled to how much water; these rights will have to be determined by the Supreme Court. The shortage of water has to do almost entirely with agricultural development as the end results of irrigation are evaporation losses. Regarding power development, the speaker pointed out that it had increased $3^1/_2$ to 4 times since 1945 and that all companies had recognized the problem so that there has not been an industry which has not been able to get power. The rates of growth were ingeniously illustrated by the speaker through the use of colored steel tapes pulled out to different lengths.

ADDRESS BY PRESIDENT QUARLES

President Quarles reported that committee appointments for the year ahead were substantially complete and he was glad to note that a majority of the members of the Board of Directors carried over from the previous year so that the administrative body is well-seasoned.

He spoke of the growth and expansion of the technical structure of the Institute, its organization into five technical divisions, and the inauguration of the three new bimonthly publications: *Communication and Electronics*, *Applications and Industry*, and *Power Apparatus and Systems*. He also considered the growth of the Institute, which has more than doubled in the last 10 years. Steps which have been taken toward the unity of the profession were outlined and assurance given that the AIEE would be kept at the forefront of this movement in accordance with the objectives expressed by over 90 per cent of those responding to the 1950 membership opinion poll. In conclusion, on behalf of the national organization, President Quarles expressed appreciation for the splendid arrangements and hospitality extended by J. E. Redmond and the 1952 Pacific General Meeting Committee. Full text of the address appears on pages 867–8 of this issue.

ADDRESSES OF WELCOME

A hearty welcome on behalf of the Salt River Power District was extended by S. A. Ward, General Manager. He explained that water was the basis of the whole economy in the region with over 230,000 acres of farm land in the desert and that the project was the second oldest and most successful irrigation project in the United States.

The welcome was seconded by Vice-President N. M. Lovell, who described the territory of the district with its high elevations, unusual geography, shifts in population with phantom ghost towns, and areas of plentiful water supply as well as areas of scarcity. Such conditions create problems peculiar to the area and the papers in the technical sessions served as a basis for the discussion of some of these special problems. The meeting was opened by J. E. Redmond, General Chairman, who introduced Pacific Coast Institute and Section officers.

TECHNICAL SESSIONS

Fifteen technical sessions were held during the four days of the meeting and many of the papers presented in these sessions were applicable to the problems of the region. This was particularly so in the sessions on the chemical industry in the west, western mining applications, transformers, industrial power systems, system engineering, and power generation, as well as the forum on the shortage of engineers.

TRANSMISSION AND DISTRIBUTION

Five papers were presented in this session with C. G. Mansfield presiding. Paul Wildi of the Pacific Oerlikon Company described field tests on 135-kv 3.5-million-kva low-oil-content circuit breakers. Discussion of this paper lead to a question regarding the rating of circuit breakers and the suggestion that the circuit breaker test code should be modified. It was explained that consideration of standards in this field has been very active and that five papers on the subject were presented at the Winter General Meeting. It was further explained that there is a difference between ratings and testing and that tests do not demonstrate the rating of a circuit breaker. The second paper presented dealt with the effects of wind, dust, and smoke on radio influence from power transmission lines. The presentation was made by A. B. Jacobsen of the University of Washington where they have the only long wind tunnel available for such tests. Conclusions reached were that there is little evidence of any effects of the wind velocity, dust, or smoke upon the amount of radio influence produced on transmission-line spans. In the third paper, Martin J. Lantz of the Bonneville Power Administration demonstrated the application of transmission-line mutual-impedance equivalent circuits which permit the solution of many problems on the d-c calculating board that heretofore have been regarded as a-c network analyzer problems.

In still another paper, "Structure Limitation Charts for Transmission Lines," presented by T. M. Austin, it was explained that the charts were developed so that the particular type of structure required for the vertical and transverse loads could be picked out readily. The last paper in this session, by R. C. Van Sickle of the Westinghouse Electric Corporation, dealt with the switching problems of high-voltage capacitors.

WESTERN MINING APPLICATIONS

In the session on western mining applications with B. E. Rector presiding, M. C. Potter of the Westinghouse Electric Corporation reviewed the special requirements of mining locomotives which encounter steep grades with heavy loads and the features incorporated to improve the performance under severe conditions.

The portability, ventilation, and compactness of portable underground dry-type power centers was brought out in a paper by Henry Gates, also of the Westinghouse Electric Corporation. The Y connection on the low-voltage side has the advantage that no other neutral is required. In discussion, A. C. Muir explained that in the bituminous fields high-tension and low-tension connections would have to be inside of the case and he inquired as to the states in which the mining departments would approve of the use of external connections at the face of the mines.

In the last paper, a comparison of high- and low-speed motors for driving ball mills was presented by Mr. Merrill of the Westinghouse Electric Corporation. The features of each type of equipment, construction, dimensions, weight, and accessibility of the windings for maintenance as well as costs and relative efficiencies were discussed to enable users to select the best type of motor.

WESTERN MINING APPLICATIONS

In this afternoon session with C. A. Poppino presiding, three papers were presented. The first paper, by J. G. Miller of the Food Machinery and Chemical Corporation, dealt with the Idaho phosphorus industry and the hydroelectric developments along the Snake River. Thirteen-thousand kilowatt-hours are required to smelt one ton of phosphorus and one plant requires capacity in excess of 60,000 kw. Large load fluctuations are encountered due to the burning off and adjustment of electrodes in the furnaces as well as to cavities which form around the electrodes and fluctuations caused by the pumping of the furnace. In the second paper, Felix Berra, Phelps Dodge Corporation, discussed the three types of electric braking on mine locomotives, regenerative braking, dynamic braking, and magnetic braking, and he described an automatic selective dynamic braking system for this type of mine haulage which is more severe than that encountered in any other section of the traction industry.

The last paper dealt with the a-c distribution in open pit copper mines. The first part of the paper which dealt with the electrical designs for operation in seven pits was presented by C. A. Poppino of the General Electric Company. In regard to requirements, he stressed the need for adequate voltage to all machines, protection to personnel, adequate grounding for protection from lightning, and the minimization of losses and improvement in power factor. Portability is also essential as the load centers shift suddenly. The second part of the paper was presented by D. B. Carson of the General Electric Company who considered the nature of the electric shovel loads with high peaks, the flexibility of portable substations, and the limiting of potential between the portable machines and ground.

AIEE officers inspect refrigeration equipment in the basement of the Hotel Westward Ho, Phoenix, during the Pacific General Meeting. Left to right: Secretary H. H. Henline, Vice-President N. M. Lovell, and President D. A. Quarles

INDUSTRIAL POWER SYSTEMS

In still another session, with P. L. Savage presiding, such problems as the continuity of service provided by secondary networks, the power supply for a nuclear research laboratory, and the grounding of industrial power systems were considered. In the paper on the power supply for nuclear research laboratory, which was presented by C. T. Graver of the University of California, the author stressed the importance of safety considerations in this type of laboratory because a highly trained personnel is employed who become very absorbed in their work. The various types of special receptacles for the different kinds of power supply, some of which provide for the grounding of portable equipment, were illustrated.

The importance and advantages of the grounding of industrial power systems were clearly demonstrated in the last paper by S. M. Dory of the General Electric Company. In the demonstration, the author showed the effects of resistance, capacitance,

and inductance to ground on an ungrounded system as well as the voltage rise that can be encountered due to a repetitive restrike type of fault. He referred to the loss of some 40–50 motors in a 3-hour period on an ungrounded system and stated as advantages of the grounded system: reduction of operating expense, improved service reliability, better system overcurrent protection, and improved lightning protection with a saving of $20–$30 per kilovolt-ampere.

Other sessions in the power field and in industry dealt with the subjects of safety, transformers, microwave applications, feedback control systems, metering and relaying, system engineering, and power generation. In the latter session such projects as the Davis Dam Power Development, the Parker-Davis Power System, a résumé of 40 years of power plant progress, and Kyrene, the Salt River Project's new modern outdoor steam plant especially designed for the climatic and operating conditions in the Southwest, were described fully. The descriptions of these projects were supplemented by papers from members of the Westinghouse Electric Corporation which dealt with the influence of power system design and protection relaying, intercooling of winding of turbine-generator units, and applications of gas turbines for central power stations.

ELECTRICAL TECHNIQUES IN MEDICINE AND BIOLOGY

To round out the scientific and research part of the program, in addition to the session on electronics and another on feedback control systems, Dr. A. M. Zarem, head of the Los Angeles Branch of the Stanford Research Institute, quickly organized a session on electrical techniques in medicine and biology about 10 days before the meeting. Dr. Zarem explained that the Committee on Electrical Techniques in Medicine and Biology was newly organized about 2 years ago and that the committee is concerned particularly with bringing about a liason between the electrical engineers and the physicians and biologists in fields where electrical techniques are used in medical and biological research, diagnosis, and therapeutics. The presiding officer was Palmer Dysart, M.D., State Medical Consultant for Vocational Rehabilitation and State Medical Consultant for Services for the Blind. Dr. Dysart spoke of the rapid advances in the medical field which had made it impossible for one to comprehend all problems which leads to the age of specialization. Electronics has extensively aided medical research but this art also has advanced very rapidly. The following papers were presented:

"Intracellular Ultramicroelectrode Recording: Problems of Electrode Resistance and Rapid Transients" by J. W. Woodbury, Jr., University of Washington, Seattle, Wash.

"A Sensitive Direct Writing Digital Pneumo-Plethysmograph" by Travis Winsor, M.D., Los Angeles, Calif.

"Remotely Controlled Stimulation in Neurophysiology" by Marcel Verzeano, M.D., J. D. French, Robert Hollis, University of California, Los Angeles, and Veterans Administration Hospital, Long Beach, Calif.

"Cardiac Defibrillation by Single Condenser Discharge" by G. L. Maison, M.D., H. E. Lape, Boston University and Riker Laboratories, Inc., Los Angeles, Calif.

Shown at the recent Pacific General Meeting are, left to right: AIEE President D. A. Quarles; Vice-President N. M. Lovell; H. B. Sargent, president of the Central Arizona Power and Light Company; S. A. Ward, general manager of the Salt River Power District; and J. E. Redmond, chairman of the meeting

THE SHORTAGE OF ENGINEERS

In this forum, two comprehensive papers were presented. One dealt with the shortage of engineers in the western states by Dr. R. J. Hannelly, Dean of Phoenix College, and the other treated the aspect of "Recruiting Future Engineers in Arizona" by W. B. Bustard, Headman, Ferguson and Carollo. Dr. Hannelly, in his paper, analyzed replies to inquiries sent to the deans of 14 western colleges and universities regarding the trends in enrollment in engineering during the last 5 years, the per cent of the demand for engineers met by the graduates, and which factors have contributed most to the need for engineers. The analysis of the replies indicated that the decreases in enrollment for the last 4 years in the western colleges was about the same as for the entire United States. The western colleges were meeting the demand for engineers by approximately 35 per cent of the need, which is comparable to the national figures; the entire nation needs about twice as many engineers as are now being produced each year. In respect to the factors which have contributed most to the need for engineers, the majority of the deans who replied to the questionnaire attributed the shortage to the needs of the Armed Forces, the increase in defense manufacturing, the complexity of the machine age, and the need for more engineers per worker as has been pointed out statistically since 1900.

In respect to recruiting future engineers in Arizona, W. B. Bustard approached the problem as a sales one which should be treated as such. To reduce the 50 per cent mortality rate in engineering, the speaker urged constant contact through the Student Branches as well as personal contact with the students. To increase the supply of properly trained high school graduates, the speaker pointed out that good results had been obtained in some cases by having high school seniors and college freshmen meet with the entering high school freshmen and talk to them about the importance of a good high school background in mathematics. Another method of approach advocated was for professional engineers to take a greater interest in the activities of this young age group through the Boy Scouts, Young Men's Christian Association, boys clubs, and sandlot athletics. The establishment of such contacts makes it easier to give advice and have it accepted.

Some of the discussion which was brought out centered about the problems of social stability and opinions in regard to the 4-year and 5-year engineering courses. One of the speakers pointed out that social stability cannot be achieved by a 3-hour course in psychology, but it can be attained by a well-rounded program of athletics and outside activities.

STUDENT TECHNICAL SESSIONS

Four papers were presented by the students in a session directed by Professor James C. Clark, Counselor of the University of Arizona. The papers presented were as follows:

"D-C Magnetic Amplifier" by Eugene Hoskinson and Jack Nelson, Oregon State College

"Farm Electrification in Saskatchewan" by R. V. Milne, University of British Columbia

"Skin Resistance Audiometry" by D. G. Peterson, University of Arizona

"A New Type of Starter for Synchronous Motors" by Raymond L. Weholt, University of Idaho

STUDENT BRANCH COUNSELORS MEETING

A joint meeting of Student Branch Counselors from Districts 8 and 9 was held in which such problems as service to the students through AIEE headquarters, the conduct of Branch activities, and the relations of students with the Sections were discussed. In respect to the conduct of Branch activities, problems of local membership were considered and such questions as to whether local dues should be collected, the amount of such dues, and whether enrolled students should be exempt from local dues, were discussed as well as how these questions were handled in joint Branches and what

constitutes the best types of meetings.

In respect to the relations of students with the Sections, such questions as "How may Student attendance at Section meetings be encouraged?" and "What are some services that Sections may render to the Branches?" were among the topics discussed.

INSPECTION TRIPS

On Wednesday, an interesting inspection trip to the Arizona Public Service Company's steam-electric generating plant was arranged. This trip also included a visit to the United States Bureau of Reclamation Switching Station and the Salt River Power District's new Kyrene steam-electric generating station. This is a completely outdoor power plant representing the latest design advancements in this type of station.

On Wednesday, an all-day trip was taken to the copper mines in the Globe-Miami District, approximately 85 miles east of Phoenix. The property of the Inspiration Consolidated Copper Company and that of the Miami Copper Company were visited. Lunch was served at the Cobre Valle Country Club.

ENTERTAINMENT

A get-acquainted social hour was held in the main floor lounge of the Hotel Westward Ho in the latter part of the afternoon on the first day. In the evening, striking color scenes of Arizona were shown by a well-known author, photographer, and lecturer.

A chuck-wagon dinner followed by entertainment was held on Wednesday evening and a banquet followed by entertainment and dancing took place on Thursday evening.

LADIES' PROGRAM

In addition to the evening events, a special program under the chairmanship of Mrs. J. E. Redmond and Mrs. T. M. Morong kept the ladies busy during the days. On the first morning, there was a coffee and get-acquainted hour. The next day featured a luncheon and fashion show, "Around the Clock With Lloyd Kiva," with Indian tribal dances between the acts. This took place at the Saddle and Sirloin Club. On Thursday, a trip was taken to the Town and Country Lodge for luncheon, swimming, cards, and relaxation.

COMMITTEES

Members of the Pacific General Meeting Committee and the chairmen of working committees were as follows:

General, J. E. Redmond, Chairman, T. M. Morong, Vice-Chairman, Americo Lazzari, Secretary; Walter Willson, *Hotels;* M. M. Bridgwater, *Treasurer and Finance;* Mrs. J. E. Redmond, *Ladies;* J. T. Kimball, *Entertainment;* M. R. Llewellyn, *Sports;* G. H. Groh, *Technical Programs;* E. A. Thomas, *Registration;* C. A. Poppino, *Inspection Trips;* C. R. Smith, *Transportation;* J. C. Clark, *Students;* Ben Ferguson, *Publicity;* I. G. Jenkins, Fay Percy, and William Doak, *Members at Large.*

Program Announced for Conference on Recording and Controlling Instruments

Instrumentation and automatic control are engineering tools that are becoming increasingly important across the whole span of technical activity. As a means of serving this widespread interest, the AIEE Subcommittee on Recording and Controlling Instruments is sponsoring a technical conference on Recording and Controlling Instruments. A primary advantage of this type of special conference is its provision of opportunity for larger groups of engineers to concentrate on one subject due to the elimination of parallel sessions. In order to broaden the service and scope of the sessions, the participation of the Instrument Society of America and of the Industrial Instruments and Regulators Division of The American Society of Mechanical Engineers has been secured. The conference will be held in Philadelphia, Pa., November 17–18 with headquarters in the Benjamin Franklin Hotel.

Four technical sessions are included in the program, devoted respectively to automatic null balance recorders, electric controlling instruments, applications and systems, and new recording instruments. Nontechnical topics of general interest have been arranged for the dinner and two luncheons. The papers will be published in printed proceedings, which will be available after the conference.

Tentative Technical Program

Sunday, November 16

5:00 to 10:00 p.m. Registration

Ballroom Foyer, Benjamin Franklin Hotel

Monday, November 17

9:00 a.m. Registration

10:00 a.m. New Developments in the Field of Self-Balancing Recorders

Presiding: G. L. Broomell, Jr., Leeds and Northrup Company, Philadelphia, Pa.

Welcome: L. R. Gaty, Chairman of the AIEE Philadelphia Section

A New Electronic Self-Balancing Recorder. *F. L. Maltby*, The Bristol Company, Waterbury, Conn.

This paper will consider design requirements imposed by present-day field of recorder application, such as: combination of various detector functions, method of making electric connections between units, and wide range of detector characteristics.

Automatic Narrow-Span Potentiometry. *E. V. Larson*, Minneapolis-Honeywell Regulator Company, Brown Instrument Division, Philadelphia, Pa.

Automatic, continuously recording instruments of industrial ruggedness and of laboratory precision are described for use in the measurement of extremely low temperatures, potentials on the order of a few microvolts, and small temperature and voltage differences. Mathematical consideration of critical factors is included.

Preliminary Development of a Magnettor Current Standard. *E. P. Felch*, Bell Telephone Laboratories, Inc., Murray Hill, N. J.; *J. L. Potter*, Rutgers University, New Brunswick, N. J.

A portable and rugged standard of current depending upon automatic comparison of a current derived magnetic field with that of a stable permanent magnet has been investigated. Techniques for attaining maximum precision and achieving temperature compensation are discussed.

Reliability of Components Used in Recording and Controlling Instruments. *W. R. Clark*, Leeds and Northrup Company, Philadelphia, Pa.

The paper discusses recent developments in the following components with particular emphasis being placed on their suitability to recording and controlling instruments: resistors, capacitors, transformers, tubes, d-c to a-c converters, balancing motors, magnetic amplifiers, and transistors.

2:30 p.m. Electric Controlling Instruments

Presiding: T. L. Mell, Minneapolis-Honeywell Regulator Company, Brown Instrument Division, Philadelphia, Pa.

The Language of Automatic Control. *G. F. Gardner*, General Electric Company, Schenectady, N. Y.

The prevailing terminology in the fields of electric and fluid control systems is compared. The general application and requirements of both electric and pneumatic systems embodying feedback control principles are illustrated by comparative schematic diagrams using the terms now current.

An Electronic Approach to Process Control. *C. J. Swartwout*, The Swartwout Company, Cleveland, Ohio

This paper discusses electronic equipment designed specifically for process control applications. Controller circuitry is explained, with particular emphasis on the circuits used for introducing adjustable integral and derivative functions. A brief mathematical analysis of controller response is included.

Fail-Safety in an Electronic Servo System. *W. E. Dion*, The Bristol Company, Waterbury, Conn.

With increasing authority delegated to electronic control systems, reliability and fail-safety become prime considerations. A system is described which provides these features without interfering with normal action or increasing system complexity unduly.

An Electric Control System for Industrial Applications. *E. T. Davis*, Leeds and Northrup Company, Philadelphia, Pa.

Basic types of control action are defined. A new electric control which provides 3-function control action is discussed. The circuits providing each type of control are explained individually. An analogy is drawn between electric and pneumatic controls and the advantages of electric controls are listed.

6:30 p.m. Dinner

Speaker to be announced

Toastmaster: E. S. Lee, General Electric Company, Schenectady, N. Y.

Tuesday, November 18

9:30 a.m. Applications and Systems

Presiding: P. A. Borden, The Bristol Company, Waterbury, Conn.

An Automatic Transfer Function Measuring and Recording System. *R. J. Ehret, J. M. Embree, E. C. Grogen, E. F. Hockschild*, Minneapolis-Honeywell Regulator Company, Brown Instrument Division, Philadelphia, Pa.

The device described gives a continuous polar plot of the transfer function of a system such as an industrial process, process controller, or instrument servo system. The system includes an accurate mechanical sine-wave generator for pneumatic, electrical, or positional outputs.

Present Status of Recording and Controlling Instruments for Steam Generation. *P. S. Dickey*, The Bailey Meter Company, Cleveland, Ohio

With the general adoption of centralized control rooms, transmission-type instruments are gaining favor over direct mechanical instruments. The relative advantage of pneumatic versus electric

systems of measurement and control is discussed for steam power plant applications.

Present Status of Recording and Controlling Instruments in the Steel Industry. *J. W. Percy*, United States Steel Company, Kearny, N. J.

This paper indicates the use made of recording and controlling instruments in the coke oven, blast furnace, open hearth, soaking pit, rolling mill, and finishing processes and their value in controlling the process to obtain the quality and quantity of the many types of steels so necessary to our modern economy and national defense.

Electrical Measurements of Process Variables in the Oil Industry. *E. J. Grace, Jr.*, Swarthmore, Pa.

Methods used in the petroleum industry for measurement of physical variables, quality, and composition of materials and products.

12:30 p.m. Luncheon

Topic to be announced

2:30 p.m. New Recording Instruments

Presiding: A. J. Hornfeck, The Bailey Meter Company, Cleveland, Ohio

Segmental Recorders. *C. G. Dell, L. P. Haner*, E. I. du Pont de Nemours and Company, Wilmington, Del.

Standard strip-chart recorders have been modified by dividing a continuous-loop chart into segments of equal length. From one to ten individual variables can be grouped into each segment, so that as many as 400 variables can be readily recorded, with a separate curve for each.

A Multipoint Sequence Recorder for Power System Application. *J. R. Leslie*, Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada

Operating sequence of relays in power-station protective schemes has been monitored with multipoint recorders, using styli resting on an electrosensitive chart. High-speed electronic starting has been used in one model.

The Anodige High-Speed Indicator and Recorder. *M. L. Kuder*, National Bureau of Standards, Washington, D. C.

The Anodige is an all-electronic analogue-to-digital converter having an accuracy of 1/4 per cent and a very high sampling rate. It includes a high-speed digital recorder. The basic converter may be used to indicate visually the readings of a multiplicity of channels.

Tektolog—A New Electrical Quantity Recorder. *H. A. Riester, Jacob Marlow*, Fielden Instrument Division of the Robertshaw-Fulton Controls Company, Philadelphia, Pa.

A recorder is described in which a lightweight vane is capacitively coupled to a second parallel vane. The movement of the second coaxial vane is mechanically coupled to a servo which both power positions a pen or slidewire and provides a feedback in the variable capacitor circuit.

Automatic Data Reduction Techniques in Radio Telemetering. *John Brinster*, Applied Science Corporation, Princeton, N. J.

This paper describes a simple special purpose computer which accepts raw data in various forms, makes appropriate nonlinear corrections, and plots such data in graphical or numerical tabular form or in a combination of these forms with the desired scale units.

AIEE Board of Directors Holds June Meeting in Minneapolis

A regular meeting of the AIEE Board of Directors was held in the Hotel Nicollet, Minneapolis, Minn., on June 26, 1952.

The minutes of the meeting of the Board of Directors held on April 17, 1952, were approved.

The following actions of the Executive Committee on membership applications, as of May 21, 1952, were reported and confirmed: 46 applicants transferred and 9 applicants elected to the grade of Member; 763 applicants elected to the grade of Associate Member; 43 applicants elected to the grade of Affiliate; 412 Student members enrolled. Of the Associate Members elected, 353 were former Student members.

Recommendations adopted by the Board of Examiners at meetings held April 17, May 15, and June 19, 1952, were reported and approved. Upon recommendation of the Board of Examiners, the following actions were taken on membership applications: 1 applicant was transferred to grade of Fellow (under old requirements); 57 applicants were transferred and 4 were elected to the grade of Member; 1 Member was reinstated; 349 applicants were elected to the grade of Associate Member; 19 applicants were elected to the grade of Affiliate; 158 Student members were enrolled.

Upon proposals, approved by the Board of Examiners, the Board voted to invite Marion Eppley, Jack Ralph Meador and Theodore Richard Walters to become Fellows of the Institute.

FINANCES

Chairman W. J. Barrett of the Finance Committee reported disbursements from general funds as follows: April, $92,946.14; May, $91,225.61; and June, $74,209.66.

Chairman Barrett reported that five loans to technical conferences, in total amount of $1,350, had been made, and that one in the amount of $300 had been repaid. All such loans in previous years have been repaid.

A comparative statement of income and expenses was presented. It showed that the receipts to May 31, 1952, were $636,729 or 65.8 per cent of the estimated income for the appropriation year, ending September 30, compared with 60.7 per cent last year. Expenses for the 8 months ended May 31 were $670,558, or 68.4 per cent of the estimated expenses for the appropriation year, compared with 68.3 last year.

Upon recommendation of the Finance Committee, the Board voted to authorize the regular travel allowance for a Joint Conference on Student Activities of Districts 8 and 9 each year, in one District or the other, this action to stand until rescinded.

The Board voted that the headquarters staff, in co-operation with the Finance Committee, prepare standard forms with reference to registration fees, fees for educational courses, and so forth, to be sent to Districts and Sections.

ACTIONS AND APPOINTMENTS

The annual report of the Board of Directors for the fiscal year which ended April 30, 1952, prepared by the Secretary, was approved.

In accordance with the requirement in Section 38 of the Constitution, the appointment of a Secretary of the Institute for the administrative year beginning August 1, 1952, was considered. H. H. Henline was reappointed.

Upon recommendation of the Committee on Constitution and Bylaws, Sections 18 and 19 of the Bylaws were amended as follows:

Section 18, paragraph 2, line 1. Immediately after the phrase "If the applicant so desires," the phrase "and his lapse of membership is not greater than three years" was inserted, Section 18 then to read:

"Sec. 18. An Affiliate, Associate Member, Member, or Fellow who has resigned in good standing may be re-elected after review of his professional record by the Board of Examiners and approval by the Board of Directors. He shall not be required to pay another entrance fee and shall renew his membership privileges upon payment of the dues for the current fiscal year in which he is re-elected.

"If the applicant so desires, and his lapse of membership is not greater than three years, he may be reinstated, retaining his original date of election or transfer, by the payment of all dues which have accrued during the interim; and he will then be entitled to such Institute publications issued during this period as may be available on the same basis as these publications have been furnished to other members."

Section 19, paragraph 2, line 1. Immediately after the phrase "If the applicant so desires," the phrase "and his lapse of membership is not greater than three years" was inserted, Section 19 then to read:

"Sec. 19. An Affiliate, Associate Member, Member, or Fellow who has been dropped as delinquent may, upon payment of all indebtedness to the Institute for which he was in arrears, be re-elected after review of his professional record by the Board of Examiners and approval by the Board of Directors. He shall not be required to pay another entrance fee and shall renew his membership privileges upon payment of the dues for the current fiscal year in which he is re-elected.

"If the applicant so desires, and his lapse of membership is not greater than three years, he may be reinstated, retaining his original date of election or transfer, by payment of all the dues which have accrued during the interim; and he will then be entitled to such Institute publications issued during this period as may be available on the same basis as these publications have been furnished to other members."

The Board authorized holding a Southern District Meeting in Louisville, Ky., April 22–24, 1953, and tentatively approved the holding of the 1957 Summer General Meeting, combined with a North Eastern District Meeting, in Buffalo, N. Y.

The Standards Committee reported the appointment of representatives and approval of Standards as follows:

Appointment of Representatives

Sectional Committee *C19*, "Industrial Control Apparatus"
Approval of revised personnel, as a cosponsor

Sectional Committee *C35*, "Rotating Electric Machinery on Railway Locomotives and Rail Cars and Trolley, Gasoline-Electric and Oil-Electric Coaches"
K. H. Gordon, representative

Sectional Committee *Z24*, "Acoustical Measurements and Terminology"
E. D. Cook, representative, to succeed P. L. Alger, resigned
F. VonVoightlander, representative, to succeed L. G. Pacent, deceased

United States Committee for Study Group XIV of International Consultative Committee on Radio (frequency band designations)
G. B. Ransom, representative

Liaison with Canadian National Committee of International Electrotechnical Commission
B. G. Ballard, to succeed A. B. Cooper, resigned

Approval of Standards

Revision of Test Code for Polyphase Induction Machines (to be submitted to American Standards Association (ASA) for inclusion in American Standard *C50*)

Revision of parts *C37.4*, *C37.5*, and *C37.9* of American Standard for Power Circuit Breakers

Revision of American Standard *C57.22*, Temperature Rise Test on Transformers

Revision of Air Switches, Insulator Units and Bus Supports, Number *22*

Revision of Fuses Above 600 Volts, Number *25*

Test Code for Low-Voltage Air Circuit Breakers (to be transmitted to ASA, with AIEE *20-1951*, for approval as an American Standard)

Preliminary report of AIEE–Edison Electric Institute–National Electrical Manufacturers Association Joint Committee on Co-ordination of Standard Basic Impulse Insulation Levels

Upon petition for the formation of a Section from the Ridgway Subsection of the Erie Section, approved by the Section and District officers concerned, the Board, upon recommendation of the Sections Committee, authorized the formation of a Ridgway Section as of August 1, 1952, with a territory composed of Cameron, Elk, and McKean Counties in Pennsylvania, all released by the Erie Section.

A suggestion that provision be made for some standard form of a badge for past Section chairmen was referred to the Sections Committee for study and report.

The first paragraph under the heading "Persons Eligible" in the rules for awards of Institute prizes was revised, and the statement regarding travel allowance under Branch Prizes was revised to specify the present allowance of 13 cents per mile one way for 800 miles or less and ten cents per mile one way for the remaining distance of a trip. (The revised rules were published in the September issue of *Electrical Engineering*, page 815.)

A written report of the activities of the Communication Division, by Chairman F. B. Bramhall of the Communication Division Committee, was presented in his absence, as he was unable to accept an invitation to be present to make a report.

The following actions were taken upon recommendation of the Committee on Student Branches:

Voted that the appropriation for each Student Branch be $1 per year per member as of November 1, in addition to the regular appropriation of $25 per year; expenditure of the $1 per member portion to be subject to no restrictions, but expenditure of the $25 portion to be subject to the same restrictions as Section appropriations.

Voted that the Board of Examiners be instructed to accept graduates of the United States Naval Academy on the same basis as graduates of curricula accredited by Engineers' Council for Professional Development.

Voted that the recommendations of the Engineering Institute of Canada be accepted with reference to admission as Associate Members of graduates of the following:

University of British Columbia, Vancouver, British Columbia
University of Saskatchewan, Saskatoon, Saskatchewan
University of Alberta, Edmonton, Alberta
University of Manitoba, Winnipeg, Manitoba
University of Toronto, Toronto, Ontario
Queen's University, Kingston, Ontario
University of New Brunswick, Frederickton, New Brunswick
Nova Scotia Technical College, Halifax, Nova Scotia
Laval University, Quebec City, Quebec
McGill University, Montreal, Quebec

Voted that the foregoing list of schools be accepted for the establishment of Student Branches.

Voted that the establishment of a Student Branch at Laval University, Quebec, be authorized.

Voted that the minutes of all meetings of the Committee on Student Branches be sent by Institute headquarters to all Branch Counselors.

As required by the bylaws of the committees, the Board confirmed appointments by President-elect Quarles of D. S. Bridgman and E. A. Walker as members of the Charles LeGeyt Fortescue Fellowship Committee, and S. B. Crary, A. C. Monteith, and J. S. Moulton as members of the Lamme Medal Committee—each for the 3-year term beginning August 1, 1952; also the appointment of O. B. Blackwell, J. F. Fairman, and K. B. McEachron as members of the Edison Medal Committee for the term of 5 years beginning August 1, 1952, and the reappointment of J. F. Calvert as chairman of the Edison Medal Committee for the year 1952–53. From its own membership, the Board elected F. O. McMillan, C. S. Purnell, and Elgin B. Robertson as members of the Edison Medal Committee for the term of 2 years beginning August 1, 1952.

Representatives of the Institute on various organizations were appointed, as listed in the September issue of *Electrical Engineering*, pages 859–60.

An announcement was made of a contribution by the General Electric Company to the Edison Medal Fund, for the purpose of increasing the fund to an amount to yield an income sufficient to cover the entire cost of the Edison medal and certificate of award each year; and the gift was accepted.

Approval was given to proposed amendments to the constitution of Engineers Joint Council dealing with election or appointment of representatives and alternates, and election of President and Vice-President.

The Board approved a statement regarding the organization and duties of the Joint AIEE–Institute of Radio Engineers (IRE) Student Branch Co-ordination Subcommittee.

Upon recommendation of the Joint AIEE-IRE Co-ordination Committee, the Board approved the addition of the Executive Secretary of IRE and the Secretary of AIEE to the membership of that committee.

President-elect Quarles was empowered to appoint Local Honorary Secretaries in cases in which terms were due to expire July 31, 1952.

Copy for a scroll to be presented to the American Society of Civil Engineers at the Centennial of Engineering, in Chicago, on September 10, was approved.

Action was taken to omit all AIEE registration fees at the Centennial of Engineering.

An invitation from The Institution of Civil Engineers, Great Britain, to submit a nomination for the Kelvin Medal award was referred to the Edison Medal Committee.

D. A. Quarles and W. Scott Hill were designated as representative and alternate, respectively, to the Celebration of the Centennial Year of the Yale School of Engineering, October 24, 1952.

The Secretary was directed to write a resolution in recognition of the distinguished services of James F. Fairman to the Institute and expressing the degree to which he will be missed in the future.

Other matters were discussed and referred to committees for study and report.

ATTENDANCE

Present at the meeting were: *President* F. O. McMillan; *Past Presidents* J. F. Fairman, T. G. LeClair; *Vice-Presidents* H. R. Fritz, E. S. Lammers, Jr., N. M. Lovell, J. A. McDonald, F. W. Norris, J. R. North, C. S. Purnell, J. C. Strasbourger, W. R. Way; *Directors* Walter J. Barrett, F. R. Benedict, R. F. Danner, E. W. Davis, D. D. Ewing, C. W. Fick, A. H. Frampton, M. D. Hooven, Elgin B. Robertson, H. J. Scholz; *Secretary* H. H. Henline; By invitation: President-elect Donald A. Quarles; incoming Vice-Presidents W. L. Cassell, W. Scott Hill, C. Myron Lytle; incoming Directors N. C. Pearcy, Andrew C. Muir; incoming Treasurer N. S. Hibshman.

AIEE Officers to Be Nominated for 1953 Election

For the nomination of officers to be voted upon in the spring of 1953, the AIEE Nominating Committee will meet in New York, N. Y., in January 1953. The officers to be elected are: a president, a treasurer, three directors, and five vice-presidents, one from each of the even-numbered geographical Districts. Fellows only are eligible for the office of president; Members and Fellows for vice-president, directors, and treasurer.

To guide this committee in performing its constituted task, suggestions from the membership are, of course, highly desirable. To be available for consideration of the committee, all suggestions must be received by the secretary of the committee at Institute headquarters not later than December 15, 1952.

In accordance with the provisions in the constitution and bylaws, quoted in the following paragraphs, actions relating to the organization of the Nominating Committee are now under way.

Constitution

29. There shall be constituted each year a Nominating Committee consisting of one representative of each geographical District, elected by its executive committee, and other members chosen by and from the Board of Directors not exceeding in number the number of geographical Districts; all to be selected when and as provided in the bylaws. The Secretary of the Institute shall be the secretary of the Nominating Committee, without voting power.

30. The executive committee of each geographical District shall act as a nominating committee of the candidate for election as vice-president of that District, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

31. The Nominating Committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The Nominating Committee shall name, on or before January 31 of each year, one or more candidates for president, treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical Districts, if received by the Nominating Committee when and as provided in the bylaws; otherwise the Nominating Committee shall nominate one or more candidates for vice-president(s) from the District(s) concerned.

Bylaws

Sec. 23. During September of each year, the Secretary of the Nominating Committee shall notify the chairman of the executive committee of each geographical District that by December 15 of that year the executive committee of each District must select a member of that District to serve as a member of the Nominating Committee and shall, by December 15, notify the Secretary of the Nominating Committee of the name of the member selected.

During September of each year, the Secretary of the Nominating Committee shall notify the chairman of the executive committee of each geographical District in which there is or will be during the year a vacancy in the office of vice-president that by December fifteenth of that year a nomination for a vice-president from that

Philadelphia Section Officials for 1952–53

ront row, left to right: W. G. Amey, Manager; M. J. A. Dugan, Manager; H. H. Sheppard, Jr., Past Chairman; H. Bany, Treasurer; . L. Gibble, Vice-Chairman; L. R. Gaty, Chairman; S. R. Warren, Sr., Past Chairman; W. F. Denkhaus, Manager; G. B. Schleicher, Manager; W. F. Henn, Chairman, Special Advisory Committee. Second row, left to right: B. H. Zacherle, Manager; W. O. Mascaro, Manager; E. B. Shew, Chairman, Student Activities Committee; L. M. Rodgers, Manager; E. F. Jones, Chairman, Membership Committee; E. J. Casey, Chairman, Fellowship and Attendance Committee; H. A. Dambly, Chairman, Committee National Officers Candidates; L. S. Brumgard, Chairman, Secondary Schools Committee; W. E. Scholz, Representative, Philadelphia Technical Service Council; R. R. Wagstaff, Chairman, Related Activities Committee; U. R. Lamay, Assistant to Treasurer. Third row, left to right: C. U. Buraster, Chairman, Discussion Groups Committee; W. P. Magee, Chairman, Instruments and Measurements Discussion Group; J. M. Bracken, Vice-Chairman, Discussion Groups Committee; H. L. Wienstein, Chairman, Industrial Practice Group; G. E. Grosser, Assistant o Secretary; N. B. Timpe, Chairman, Publicity Committee; W. G. Salmonson, Vice-Chairman, Communications Discussion Group; . E. Moore, Chairman, Technical Conference on Controlling and Recording Instruments Committee; S. Charp, Chairman, Basic Science Discussion Group; R. S. Hewett, Chairman, History Committee; R. L. Halberstadt, Chairman, Prize Paper Committee; R. E. Cordray, Chairman, Transfers Committee; E. M. Gore, Chairman, Electronics Discussion Group; W. G. Harlow, Chairman, Power Systems Discussion Group

District, made by the District executive committee, nust be in the hands of the Secretary of the Nominating Committee.

Between October first and December fifteenth of each ear, the Board of Directors shall choose five of its nembers to serve on the Nominating Committee and hall notify the secretary of that committee of the names o selected and shall also notify the five members selected.

The Secretary of the Nominating Committee shall give he fifteen members so selected not less than ten days' notice of the first meeting of the committee, which shall e held not later than January thirty-first. At this neeting, the committee shall elect a chairman and hall proceed to make up a ticket of nominees for the offices to be filled at the next election. To insure that ull consideration be given to all suggestions from the general membership, they must be in the hands of the ecretary of the committee by December fifteenth. The nominations as made by the Nominating Committee hall be published in the March issue of *Electrical Engineering*, or otherwise mailed to the Institute membership not later than the first week in March.

Independent nominations may be made in accordance with provisions in article VI, section 32, of the constitution and section 24 of the bylaws, which are quoted below:

Constitution

32. Independent nominations may be made by a petition of twenty-five (25) or more corporate members sent to the Secretary when and as provided in the bylaws; such petitions for the nomination of vice-presidents shall be signed only by members within the District concerned.

Bylaws

Sec. 24. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with article VI, section 32 (Constitution), must be received by the Secretary of the Nominating Committee not later than March 25 of each year, to be placed before that committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the Nominating Committee in accordance with article VI of the Constitution and sent by the Secretary to all qualified voters on or before April 15 of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

(*Signed*) H. H. Henline
Secretary

AIEE, IRE to Cosponsor Western Computer Conference

The first meeting of the Western Computer Conference will be held at the Hotel Statler in Los Angeles, Calif., February 4–6, 1953. This conference will be sponsored by the joint Computer Conference Committee of the Institute of Radio Engineers and the AIEE.

Papers to be presented at the conference will appeal to both prospective users of electronic computers and to the designers of these instruments, according to the co-chairmen, Dr. Gilbert McCann of the California Institute of Technology and Dr. Harry Huskey of the National Bureau of Standards at the University of California at Los Angeles. Information presented will be equally divided between application and design problems and will cover both analogue and digital computers.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Division

Committee on Communications Switching Systems (*John Meszar, Chairman; A. E. Frost, Vice-Chairman; William Keister, Secretary*). Switching technology is rapidly increasing in scope and complexity. The intriguing aspects of this branch of engineering have been little known except to the group of engineers directly concerned with the development and operation of telephone switching systems. In the past 30 years, automatic telephone switching systems have grown from relatively simple beginnings into what are perhaps the most complex machines in existence today. Switching principles and techniques which have long been used in these telephone systems are now also being employed in digital computers and other automatic control systems.

The committee feels a twofold responsibility of, first, bringing to those concerned the latest advances in the art, and, second, acquainting a larger segment of the engineering profession with the switching art. Serving both objectives was a successful symposium on "Nation-wide Toll Dialing" held at the Summer General Meeting. In the near future, the committee is planning to continue this effort with two types of meetings, those reporting technical progress and directed toward communications engineers, and those of a more general nature which will include demonstrations to bring out the highly interesting facets of the switching art.

General Applications Division

Committee on Domestic and Commercial Applications (*T. H. Cline, Chairman; T. C. Johnson, Vice-Chairman; J. H. T. Miller, Secretary*). On May 16 and 17, the committee sponsored its third annual Technical

Conference on Domestic Appliances and had a most successful meeting. As a result of its success with technical conferences over the past 3 years, the committee is planning to sponsor a 2-day Technical Conference on Domestic Appliances to be held in Louisville, Ky., in co-operation with the AIEE Louisville Section. It will be held in May 1953.

The Subcommittee on Farm Electrification is again actively working on the program of the National Farm Electrification Conference to be held in October 1952 in Detroit, Mich. The committee is actively sponsoring some of the papers to be given at this conference.

Plans are now well along in preparing for the committee's program to be sponsored at the Winter General Meeting in January 1953 on Heat Pumps and Space Heating. Tremendous interest has been developed in this subject over the past few years and the committee is anticipating a most successful meeting.

Industry Division

Committee on Chemical, Electrochemical, and Electrothermal Applications (*J. Z. Linsenmeyer, Chairman; F. S. Glaza, Vice-Chairman; E. H. Browning, Secretary*). Under the supervision of Professor R. M. Wainwright, the Cathodic Protection Subcommittee is preparing a series of articles on "Cathodic Protection." The 5-year program of the subcommittee is progressing satisfactorily and involves co-operation with other societies, industrial organizations, and universities. In conjunction with the Chemical and Petroleum Industry Divisions, a session is planned on "Cathodic Protection for Refineries and Pipe Lines" at the 1952 Fall General Meeting in New Orleans, La. A committee meeting is also scheduled at that time.

The Chemical Industry Subcommittee, in conjunction with the Coal Mining Subcommittee, is sponsoring sessions for the 1953 Middle Eastern District Meeting at Charleston, W. Va. In co-operation with F. L. Lawton, a session on "Chemical and Allied Industries in Western Canada" is being prepared for the 1953 Pacific General Meeting at Vancouver, British Columbia, Canada.

A session of the Electrochemical Processes Subcommittee is being planned by W. E. Gutzwiller for the 1953 Winter General Meeting.

The Storage Batteries Subcommittee of this committee is continuing its work on Standards.

Power Division

Committee on Insulated Conductors (*C. T. Hatcher, Chairman; R. J. Wiseman, Vice-Chairman; M. H. McGrath, Secretary*). The organization of the Committee on Insulated Conductors has been completed for the year 1952–53. There are 95 members and special members who make up 12 subcommittees. All subcommittees are actively engaged in work which has been assigned to them and in accordance with past experience this work will result in the compilation of papers by individuals for presentation to the industry.

The copper shortage during the past year resulted in bringing aluminum to the forefront for use in conductors. Recognizing the country-wide interest in this subject, the Insulated Conductors Committee, in conjunction with the Industrial Power Committee, is sponsoring two sessions at the New Orleans meeting this month on the subject of aluminum for power and industrial use.

Subcommittee on Fault Limiting Devices of the Protective Devices Committee. It was reported at the meeting of the Committee on Protective Devices, in May, that on the status of three application guides, *49-780*, *49-281*, and *49-283*, which this subcommittee is revising, considerable progress has been made and present plans are to have them all issued before the end of 1952.

In order to assure a consensus favorable to the guides in their final form, copies will be sent to all subcommittee members and a letter ballot taken before presentation to the Protective Devices Committee for its approval.

Referring in particular to the "Guide for the Application of Ground Fault Neutralizers" (*49-283*), it was requested that the Protective Devices Committee go on record as approving the terminology which the working group on this project has employed. There has been some controversy on this matter, and it is important to have it clarified before the circulation of the final draft.

The question arose over the use of the term "neutralizer grounded" in the guide in preference to the term "resonant grounded." AIEE Standard Number *32* defines the device employed to produce this type of grounding as a "ground fault neutralizer" (*32-1.19*), and it refers to a system in which such a device is employed as "resonant grounded" (*32-1.09*). A majority of the working group favor the more consistent and descriptive term "neutralizer grounded" to refer to a system employing the "ground neutralizer" device rather than the term "resonant grounded" device.

Following discussion, a motion was made and passed unanimously by the committee, stating:

"The Protective Devices Committee approved the use of the term "neutralizer grounded" in the revised application guides *49-290*, *49-201*, and *49-283*, with a reference to resonant grounding as defined in AIEE Standard Number *32*."

Science and Electronics Division

Committee on Instruments and Measurements (*J. H. Miller, Chairman; J. E. Hobson, Vice-Chairman, West; J. G. Reid, Jr., Vice-Chairman, East; Ernst Weber, Secretary, East; W. S. Pritchett, Secretary, West*). A luncheon meeting of the Instruments and Measurements Committee was held on June 25 in Minneapolis. Quite a number of the committee members were able to attend and most of the subcommittees made reports.

The chairman announced that the Instruments and Measurements Committee had voted on its acceptance of Standard Number *4*, "Measurement of Voltage in Dielectric Tests," and the only comments on the Standard were on minor matters of an editorial nature.

This Standard, then, on which the subcommittee under Mr. Lusignan has labored for 2 years, will be presented to the Standards Committee by the liaison representative, Mr. Koenig, at its first meeting this fall. A great deal of new material is included in this Standard and it should be of considerable value to those working in the high-voltage field.

The proposed power test code is ready for distribution to the members of the committee for a trial period of 1 year. The subcommittee, under C. J. Zeller of New York, has co-ordinated a great deal of data over and above that of the older code which should be most helpful.

The Joint Subcommittee on Telemetering (jointly with Institute of Radio Engineers) planned the conference held at Long Beach, Calif., on August 26–27. W. J. Mayo-Wells of the Johns Hopkins University is currently chairman of the joint subcommittee and reports some 15 papers presented at that conference. The meeting appeared to be somewhat heavily weighted in favor of mobile telemetering, but this was quite understandable in view of current interest in obtaining information from objects in flight.

The revised organization of the Instruments and Measurements Committee seems to be functioning well and will be fully in use for the operating year 1952–53. Essentially the large number of subcommittees have been placed in eight groups, each headed by a "group subcommittee" with a chairman. It is believed that the new method will result in a somewhat simpler structure for handling the many projects now in work.

Subcommittee on Dielectrics of the Basic Sciences Committee (*L. J. Berberich, Chairman*). A brief review of the papers presented at the Winter and Summer General Meetings indicates that the subcommittee has brought to the Institute a variety of papers covering the properties of new materials and also the results of basic studies of dielectric behavior.

Most of the papers which were presented were prepared by chemists, and thus the subcommittee has been instrumental in bringing before the Institute some of the chemical thinking and the results of chemical progress in this field. A good percentage of the papers presented have been published by the Institute, and they are thus preserved as a part of the permanent literature in the field of dielectrics.

The subcommittee has a total membership of 22 engineers, chemists, and physicists, and they represent a considerable segment of the electrical and also of chemical industries.

The subcommittee is planning to have its next meeting during the National Research Council Conference on Electrical Insulation, which is scheduled for October 2–4 at Lenox, Mass.

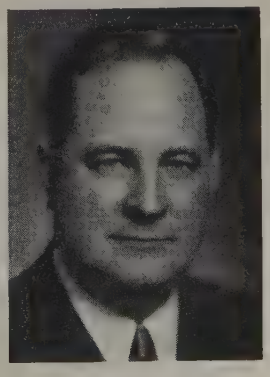
AIEE PERSONALITIES . . . . .

O. E. Buckley (M '19, F'29), Chairman of the Board, Bell Telephone Laboratories, Inc., New York, N. Y., retired September 1, 1952. Born in Sloan, Iowa, on August 8, 1887, he was graduated from Grinnell College in 1909 with a bachelor of science degree, and from Cornell University in 1914 with a doctor of philosophy degree in physics. He joined the Bell Laboratories in 1914 but his career was interrupted by service in the United States Army. He was placed in charge of the research section of the Signal Corps. He returned to Bell Laboratories in 1919 and continued his work on submarine telegraph cables. He also conducted research in the field of wire transmission. In 1927 he was appointed assistant director of research; in 1933, director of research; executive vice-president in 1936; president in 1940; and chairman of the board in 1951. Since 1948, Dr. Buckley has served as a member of the General Advisory Committee of the Atomic Energy Commission. In 1951 he was named by President Truman to head a group of the nation's top scientists who would act on a science advisory committee to advise on matters relating to scientific research and development for defense. He was awarded the Medal of Merit for his services in World War II. In honor of Dr. Buckley, the Bell Telephone Laboratories and the American Physical Society have established the Oliver E. Buckley Solid State Physics Prize, consisting of an annual prize of $1,000 to be awarded by the society to a person who has been adjudged to have made a most important contribution to the advancement of knowledge in solid state physics within the 5 years immediately preceding the award. Dr. Buckley is a member of the Franklin Institute, the American Association for the Advancement of Science, and the American Physical Society. A very active member of the Institute, he has served as Vice-President, District 3 (1946–48), and on the following committees: Electrophysics, Basic Sciences (1926–37, Chairman 1929–31, 1946–48), Research (1934–40), Charles LeGeyt Fortescue Fellowship (1939–45, Chairman 1941–45), Finance (1946–47), Edison Medal (1944–49), Technical Program Committee, Meetings and Papers (1929–31, 45–47), Executive (1946–48), and Communications and Science Co-ordinating (1947–48).

S. H. Mortensen (AM '09, F '20, Member for Life), chief electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., retired July 31, 1952. Mr. Mortensen was born in Eskelund, Denmark, November 4, 1879, and was graduated from the Polytechnicum of Mittweida, Germany, in 1902 with the degrees of electrical and mechanical engineer. Previously, from 1896 to 1898, he had gained experience as an apprentice in various Danish firms and attended technical schools in Thisted and Aarhus and had served as a second lieutenant in the Danish Army. Leaving Denmark for the United States, he was employed from 1903 to 1905 as draftsman and mechanical engineer by the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), Pittsburgh, Pa. In 1905 he joined the Bullock Works (then the Bullock Electric Company) of the Allis-Chalmers Company, Cincinnati, Ohio, as draftsman and designer of d-c motors and turbogenerators and in 1908 was transferred to Milwaukee. In the latter year, also, he was naturalized in the United States. After shifting his work to a-c turbogenerators in 1909, he was made designing electrical engineer in charge of synchronous motors and generators in 1911. He was named engineer in charge of the company's a-c design in 1932 and chief electrical engineer in 1942. He was awarded the AIEE Lamme Medal for 1944 "for his pioneer work in the development of self-starting synchronous motors and for his contributions to the development of large hydraulic and steam-turbine-driven generators." The same year he received the honorary degree of doctor of engineering from Illinois Institute of Technology. Mr. Mortensen holds a number of patents for specific design features of large salient-pole machines and large air- and hydrogen-cooled turbogenerators. He is a member of the National Electrical Manufacturers Association and Eta Kappa Nu. Mr. Mortensen has served as a director (1943–47) and on the following committees: Membership (1925–30), Electric Machinery (1932–44), Applications to Iron and Steel Products (1934–35), Standards (1935–48), Publication (1940–41), Technical Program (1942–50), Edison Medal (1944–46), Code of Principles of Professional Conduct (1945–47), and Members-for-Life Fund (1951–52).

O. E. Buckley

S. H. Mortensen



J. J. Pilliod

J. J. Pilliod (M '17, F '34), assistant chief engineer, American Telephone and Telegraph Company, New York, N. Y., will retire October 31, 1952. Mr. Pilliod was born in Chillicothe, Mo., October 8, 1887, and received the degree of electrical engineer in 1908, and the honorary degree of doctor of engineering in 1939 from Ohio Northern University. In 1908 he became associated with the American Telephone and Telegraph Company and filled various positions in both plant operation and engineering work at Maumee, Ohio; Chicago, Ill.; Indianapolis, Ind.; and New York, N. Y., until in 1914 he was named division plant engineer, long-lines department, Chicago. Four years later he was in New York as engineer of transmission, long-lines department, and was in charge of a group handling transmission engineering work involved in the construction and operation of long-distance telephone and telegraph plants. In 1920 he was appointed engineer in charge of the long-lines engineering department in New York. Mr. Pilliod was made general manager of the long-lines department in 1941 and 2 years later was appointed assistant chief engineer of the company with system-wide activities in broad engineering work. From October 1942 to April 1943 he was loaned to the War Department as Chief of Signal Section, Production Division, Army Service Force. Mr. Pilliod has been a very active member of the AIEE, serving on the following Institute general committees: Membership (1924–25); Communication (1933–37, 1945–48, Chairman 1945–48); Special Committee on Postwar Planning (1943–45); Standards (1945–47); Award of Institute Prizes (1945–49); Technical Program (1945–47); Board of Examiners (1945–50); Members-for-Life Fund (1952–53); and Liaison Representative on Standards Committee (1951–53). He has also served as a representative or alternate on the Electrical Standards Committee, American Standards Association (ASA), (1945–53); Standards Council, ASA, (1945–47); and United States National Committee of the International Electrotechnical Commission (1945–53). He is the author of a number of technical papers on wire and radio telephony.

R. W. Sorensen (AM '07, F '19, Member for Life), professor emeritus of electrical engineering, California Institute of Technology, Pasadena, retired September 1, 1952. He has been on half-time retirement from his professorial duties for the past 2 years. Dr. Sorensen was born in Wabaunsee County, Kans., in 1882 and received his bachelor of science degree from the University of Colorado in 1905. He later received the degrees of electrical engineer and doctor of science. He came to California Institute of Technology in 1910 with the purpose of starting a department of electrical engineering. After his appointment as professor emeritus in 1950, he was honored by a group of his former students when they inaugurated the Royal W. Sorensen Graduate Fellowship in Electrical Engineering. He holds the most valuable engineering service scroll of the Engineers and Architects Association of Los Angeles and was elected the first Eminent Member of Eta Kappa Nu. He has held offices in the Society for Promotion of

Engineering Education and is a member of the Engineering Council of Founder Societies of Southern California, the American Association for the Advancement of Science, the Association of American University Professors, Sigma Xi, and Tau Beta Pi. A past president of the AIEE (1940–41), Dr. Sorensen has served as a director (1936–40); vice-president, District 8 (1933–35); and on the following Institute committees: Research (1923–44, Chairman 1941–43); Education (1924–28, 1934–37, 1939–40, 1943–49); Student Branches (1927–28, 1936–40, Chairman 1938–40); Instruments and Measurements (1927–30); Lamme Medal (1933–36); Edison Medal (1938–43); Planning and Co-ordination (1939–40); Executive (1940–43, Chairman 1940–41); Membership (1939–40); Award of Institute Prizes (1941–43); Members-for-Life Fund (1944–52); Code of Principles of Professional Conduct (1947–52, Chairman 1950–51); Registration of Engineers (1948–52); and Professional Division Advisory (1950–52).

R. F. Tinnerholm (AM '30, M '45), general manager, Switchgear Department, General Electric Company, Philadelphia, Pa., retired September 1, 1952. Mr. Tinnerholm was born in New York, N. Y., on January 16, 1891. He jointed General Electric in 1907 as a drafting apprentice in Schenectady, N. Y., and was graduated from the apprentice

R. F. Tinnerholm

course in 1911. He became affiliated with the switchgear business in 1919 as a proposal engineer in Schenectady after returning from service in World War I. Mr. Tinnerholm was transferred to Philadelphia in 1927 and was placed in charge of metal panel sales, a position he held until his appointment as manager of switchgear sales in 1939. He was named general manager of the Switchgear Department in October 1947. He attended Drexel Institute and is a member of the National Electrical Manufacturers Association and the Edison Pioneers.

A. B. Gates (M '15, Member for Life), consultant on training to the general management of Eastman Kodak Company, Rochester, N. Y., has retired. He is a native of Walker, N. Y., and a graduate of Purdue University where he received his bachelor of science degree in electrical engineering in 1909. During 1909 and 1910 he did postgraduate and research work at the University of Illinois. He joined Kodak in 1930 as director of training and was named consultant on training to the general management in 1951. He is a member of the American Management Association and representative to the National Association of Manufacturers and the National Industrial Conference Board. He served the AIEE on the following committees: Education (1928–29), and Student Branches (1928–29).

W. K. Sonnemann (AM '38, M '43), senior relay engineer, Westinghouse Electric Corporation, Newark, N. J., has been named manager of the relay engineering section of the Westinghouse Meter Division. A native of Port Lavaca, Tex., Mr. Sonnemann received a degree in electrical engineering from the University of Texas in 1924. He joined the company's graduate student course at East Pittsburgh, Pa., in 1924, and left Westinghouse in 1929 to return to Texas. In 1936, he rejoined Westinghouse at the Meter Division as a relay design engineer. He served on the AIEE Relay Committee (1947–52).

E. M. Strong (AM '26, M '40), professor of electrical engineering, Cornell University, Ithaca, N. Y., has been elected president of the Illuminating Engineering Society. A graduate of Massachusetts Institute of Technology, Professor Strong has been associated with Cornell since 1924. He has served the AIEE on the following committees: Production and Application of Light (1936–47, 49–52, Chairman 1941–43), Education (1937–39, 40–41, 48–52), Student Branches (1938–48), Technical Program (1941–43), and Standards (1941–43).

David Sarnoff (M '23, F '51), Chairman of the Board, Radio Corporation of America, New York, N. Y., has been awarded the Medal of Honor by the Radio-Television Manufacturers Association for his outstanding contributions to the advancement of the radio, television, and electronics industry. Mr. Sarnoff, first to receive the annual award, was presented the medal by R. C. Sprague at the 28th Annual Convention of the association in Chicago, Ill., on June 26, 1952.

E. D. Murray (M '39), industrial specialist, Electrical Equipment Division, National Production Authority, United States Department of Commerce, has been appointed utilities engineer, Community Management Division, Los Alamos (N. Mex.) Field Office, Atomic Energy Commission. He attended the University of Nevada and the Univeristy of California. From 1940 to June 1951 he was supervising electrical utilities engineer with the California Department of Public Works. He is a member of the American Society of Mechanical Engineers and the Engineers Club of San Francisco.

M. B. McDavitt (M '40, F '51), director of switching development, Bell Telephone Laboratories, New York, N. Y., has been appointed director of transmission development. Mr. McDavitt has been associated with the Bell System since 1925, after receiving degrees from the University of Virginia and Massachusetts Institute of Technology. **A. J. Busch** (AM '24, F' 51), director of switching systems development, succeeds Mr. McDavitt. Mr. Busch has been with the Bell System since 1922 and has devoted his efforts to dial switching systems.

D. D. Knowles (M '39), manager, Electronics Engineering Department, Westinghouse Electric Corporation, Bloomfield, N. J., has been appointed staff assistant to the manager of engineering for the Electronic Tube Division. Mr. Knowles joined Westinghouse at East Pittsburgh, Pa., in 1932, headed the gaseous conduction section of the research laboratories in 1930, and 6 years later became head of the electronics section. For the past 10 years, he has been manager of the electronics engineering department. He has served the AIEE on the Electronics Committee (1945–46, 47–48).

J. D. McLellan (AM '48) vice-president and general manager, J. H. Bunnell and Company, Brooklyn, N. Y., has been named plant manager for Marion Electrical Instrument Company, Manchester, N. H. He is an engineering graduate of the University of Toronto. He is a member of the Society for the Advancement of Management.

W. J. Lind (AM '36, M '46), manager, Lamp and Lighting Division, Canadian General Electric Company, Ltd., Vancouver, British Columbia, Canada, and **G. J. Taylor** (M '44), eastern sales manager, Day-Bright Lighting, Inc., New York, N. Y., have been elected vice-presidents of the Illuminating Engineering Society for the Pacific Northwest Region and the Northeastern Region, respectively.

OBITUARY

Fred Charles Hanker (AM '05, M '13, Member for Life), retired, Westinghouse Electric Corporation, died July 26, 1952, at Stanford, Calif. Mr. Hanker was manager of central station engineering for Westinghouse at East Pittsburgh, Pa., prior to his retirement in 1935. He was born at Toledo, Ill., September 13, 1880, and received his technical education at Purdue University, being granted a bachelor of science in electrical engineering degree in 1902. He entered the apprentice course of the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) in 1902 and remained in this course until 1904. From 1905 to 1906 his work consisted of d-c machine design. From 1906 to 1909 he was an assistant in the office of B. G. Lamme, chief engineer. From 1911 until his retirement he was in the central station engineering department, rising to the position of manager. In the 1950 midcentury edition of the *Westinghouse Engineer*, he was hailed as having played an outstanding part in the growth of the electrical industry. Mr. Hanker is a former director of the Institute (1927–31) and had served on the following AIEE committees: Electrochemistry and Electrometallurgy (1920–21, 1928–31);

Marine (1914–15); Power Stations, Power Generation (1918–24, 1928–33); Protective Devices (1919–20, 1921–31, 1937–43); Standards (1917–22); Safety Codes (1927–28); Technical Program (1933–35); and on the United States National Committee of the International Electrotechnical Commission (1928–32).

Abdullah Feyzi Hamdi (AM '18, M '21, F '46), professional engineer, Philadelphia, Pa., died July 24, 1952. Mr. Hamdi was born in Istanbul, Turkey, January 16, 1891, and came to the United States in 1911. He was graduated from Columbia University in 1916 with the degree of electrical engineer, receiving the next year the degree of master of arts in physics. After graduation in 1916, Mr. Hamdi served as a laboratory assistant at Columbia and taught evening school classes at Columbia University and Cooper Union. He was employed by the New York Edison Company in 1917 as a laboratory assistant in the test department; in 1918 he was made foreman of the standardizing department and in 1919 a general foreman in the test department. He was promoted to assistant engineer of the test department in 1924 and from 1927 to 1929 he was assistant engineer in the meter department. He went to Philadelphia, Pa., in 1929 where he served as engineer with the Hall Electric Heating Company, Inc. He returned to Turkey in 1934 as chief of the Bureau of Electrification in the Ministry of Economy of the Turkish Republic. In 1935 he became Director General, Department of Electric Research, Ministry of Public Works, in charge of surveying and mapping power potentialities of the country and the development of a national program based on the survey for the construction of plants. In 1945 he headed a group of engineers on an official mission to the United States to survey water power resources. He returned to the United States in 1947.

Frank F. Ambuhl (AM '17, M '26), assistant to chief engineer, Toronto Hydro-Electric System, Toronto, Ontario, Canada, died recently. Mr. Ambuhl also served as a departmental executive, and had retired last year because of illness. He was born January 25, 1886, in Farina, Ill., and received his early engineering experience with Ford, Bacon and Davis, Engineers, Birmingham, Ala., in electrical construction work. In 1908 he entered the employ of Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), Langdale, Ala., where he was engaged in the installation and operation of a 5-unit hydroelectric plant. During 1910–11 he was associated briefly with the Macon (Ga.) Railway and Light Company as superintendent of construction and with J. C. White Corporation, Atlanta, Ga., in overhead rehabilitation construction. From 1911 to 1912 he was again affiliated with Westinghouse as erecting engineer, first near Atlanta and later in Charlotte, N. C. In 1912 he left that company to become resident electrical engineer for Big Dome Gold Mines, Ontario, where he served until 1913. From 1913–17, he was assistant engineer of stations, Toronto Hydro-Electric System, and from 1917–19 was general manager and chief engineer, National Abrasive Company, Hamilton and Niagara Falls, Ontario. When the plant closed shortly after the end of World War I, he rejoined the Toronto Hydro-Electric System as assistant chief engineer. Mr. Ambuhl had served on the following AIEE committees: Electrochemistry and Electrometallurgy (1919–20); Automatic Stations (1930–46, Chairman 1942–44); Technical Program (1942–44); and Standards (1942–44).

Bertrand Gillette Jamieson (AM '08, M '17, F '22, Member for Life), retired, Commonwealth Edison Company of Chicago, Ill., died on August 3, 1952. He was born on February 27, 1874, in Texas, and came to Chicago in 1893. He was graduated from the Armour Institute of Technology in 1897 with a bachelor of science degree in electrical engineering. Following his graduation, he joined the Chicago Edison Company and continued with that company and its successor, the Commonwealth Edison Company, until his retirement in 1934. For many years he was in charge of electrical design of generating stations and substations as engineer of inside plant. Among his many contributions to the art of power station design was the isolated phase system of switchhouse construction. He had served as Vice-President of the Great Lakes District of the AIEE from 1926–28 and had served the Institute on the following committees: Protective Devices (1923–25, 1928–29); Standards (1923–29); Edison Medal (1926–28); and Electrical Machinery (1928–29).

Lewis Henry Daniels (AM '41), industrial supervisor, Westinghouse Electric Corporation, Detroit, Mich., died August 5, 1952. He was born in Manistee, Mich., July 5, 1911. He attended Michigan State Teachers College and received his bachelor of science degree in electrical engineering in 1940 from the University of Michigan. He joined Westinghouse in 1940, having previously worked for General Motors Corporation and the Ford Motor Company. He was a member of the Engineering Society of Detroit.

Arthur Laurie Abbott (AM '06, M '13, F '44, Member for Life) engineering department, National Electrical Manufacturers Association, New York, N. Y., died July 26, 1952. Mr. Abbott was born in Albert Lea, Minn., March 14, 1873, and was graduated in electrical engineering from the University of Minnesota in 1897. From 1899 to 1924 he was an electrical contracting engineer in St. Paul, Minn. In 1924 he was technical director of the Electragist Association, now National Electrical Contractors Association. Since 1928 he had been technical advisor to the Uniform Legislation Department of the National Electrical Manufacturers Association. Mr. Abbott was the author of the National Electrical Code Handbook and the Electrical Contractors Estimating Manual and also contributed many articles to leading technical publications. He was the first man to develop standards for electrical estimating which now are used widely in the electrical construction industry.

Louis Anton Buese (AM '31), senior vice-president, Hawaiian Electric Company, Ltd., Honolulu, Hawaii, died on July 11, 1952. He was born on June 13, 1887, in Republic, Mich., and attended the University of Michigan. In 1908 he joined the Warren Bisbee Railway Company, Bisbee, Ariz., and 4 years later became general foreman in the electrical department of the Oregon Shortline Railroad at Pocatello, Idaho. During 7 years with the company he rose to the position of electrical engineer in charge of design, construction, and operation of electric generating equipment. Mr. Buese entered business for himself in 1919, but after 2 years he moved to California and became associated with the Los Angeles (Calif.) Gas and Electric Corporation. In the course of 15 years with the company he rose to the position of assistant superintendent of the electrical department. In 1937 the Los Angeles Gas and Electric system was sold to the Bureau of Power and Light, operated by the city. Mr. Buese remained with this organization as a member of the design and construction division. In 1937 he joined the Hawaiian Electric Company as design engineer. He became vice-president and executive engineer in 1945 and senior vice-president in 1947.

Albert B. Paterson (M '22), chairman of the board, New Orleans (La.) Public Service, Inc., died August 6, 1952. He was born in Blantyre, Ontario, Canada, January 20, 1883. From 1906 to 1910 he was engineer and general manager of the Meridian (Miss.) Light and Railway Company, and served as second vice-president from 1910 to 1917. From 1917 to 1918 he was a special representative for Henry L. Doherty and Company, New Orleans. He joined the New Orleans Railway and Light Company as engineer and general superintendent of the railway department in 1921. He began his career with New Orleans Public Service, Inc., in 1923, becoming president of the company in 1930 and remaining in that position until 1951 when he was elected chairman of the board. Mr. Paterson was a director of Middle South Utilities, a director of Gulf Mobile and Ohio Railroad, a trustee of Edison Electric Institute, and a member of The American Society of Mechanical Engineers.

MEMBERSHIP • • •

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before October 25, 1952, or December 25, 1952, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Cohen, S. S., 259 E. Wells St., Milwaukee, Wis.
Hamid, A., Public Works Dept., Electricity Branch, Lahore, Pakistan
Harmon, R. N., Westinghouse Radio Stations, Inc., Washington, D. C.
Jordan, C. A. (re-election), General Cable Corp., Perth Amboy, N. J.
Kropf, V. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Millar, J. Z., Western Union Tel. Co., New York, N. Y.

6 to grade of Member

OF CURRENT INTEREST

Light and Vision Institute Demonstrates Principles and Practices of Lighting

The Light and Vision Institute, a unique center for the demonstration of lighting principles and practices and for the solution of lighting problems, has been incorporated in the offices of the Holophane Company, Inc. This center, which is also a lecture hall, forms an integral part of the company's research program. Its facilities permit the demonstration of all types of prismatic light control, and of the latest developments in lighting equipment and methods. They also permit the investigation and checking of mechanical and optical performance, and of field practices.

From a panel on the speaker's platform, each exhibit can be individually lighted, providing dramatic impact to whatever the speaker may be demonstrating. The focal point of the entire Light and Vision Institute is a giant light control board divided into a series of compartments. Each of the compartments shows a specific example of redirecting light through prismatic action. The action of uncontrolled light from a bare lamp is first demonstrated. Then follows the action of refracting prisms on individual rays, and of reflecting prisms. This is succeeded by the action of combinations of these prisms in various forms and arrangements, and is carried through into the action of the actual refractors, lenses, and reflectors used in commerce and industry today. The demonstration of the 4-way refractor so widely used in street lighting today is particularly spectacular. Forty individual rays appear inside the circular section of the refractor, distributed equally around its interior; but they emerge in four distinct beams of ten rays each, gathered together to go up and down the intersecting roadways.

With the aid of these panels the visiting architect or engineer can relate the light action to his current project and select the type best suited. The board also aids their client to understand why the selected action is best.

Advanced practice is demonstrated dramatically. Included is a new conception of vertical surface lighting, a Controlens* with concave cross-section one-way, producing more than twice the efficiency of anything previously known. Another is a new square lens that is concaved differently across the diagonals and across the center axes. Although this type of lens was theoretically possible for a long time it had to await the invention of a machine which would cut the prisms in the mold accurately along the variously curving surfaces. It has the practical advantage of reducing the brightness of the lens by one-third while increasing its light output by 25 per cent.

The most modern type of surgery lighting is shown delivering 3,000 foot-candles of illumination. It is built flush into the ceiling, and facilitates the color televising of operations. The fundamentals of Illumineering*—how much light to use, the engineering choice and specification of reflection factors, their translation into colors, and the scientific determination of visual comfort factors—are demonstrated. Photographic transparencies that can be back-lighted at will from the control panel on the speaker's rostrum, border three walls of the room, reproducing recent outstanding lighting jobs.

Every way of using the prism can be shown here, from the actual fundamental prismatic element, with its exact action, through the unit that employs this particular element, with the actual photometric characteristics of the unit. Its appearance and performance in an existing installation can be projected on to the screen for the benefit of an audience. One of the fascinating items to many visitors is the Refractolens,* whereby widespread lighting can be accomplished from units mounted on the fronts of buildings, without the use of poles. St. Paul, Minn., has the first installation.

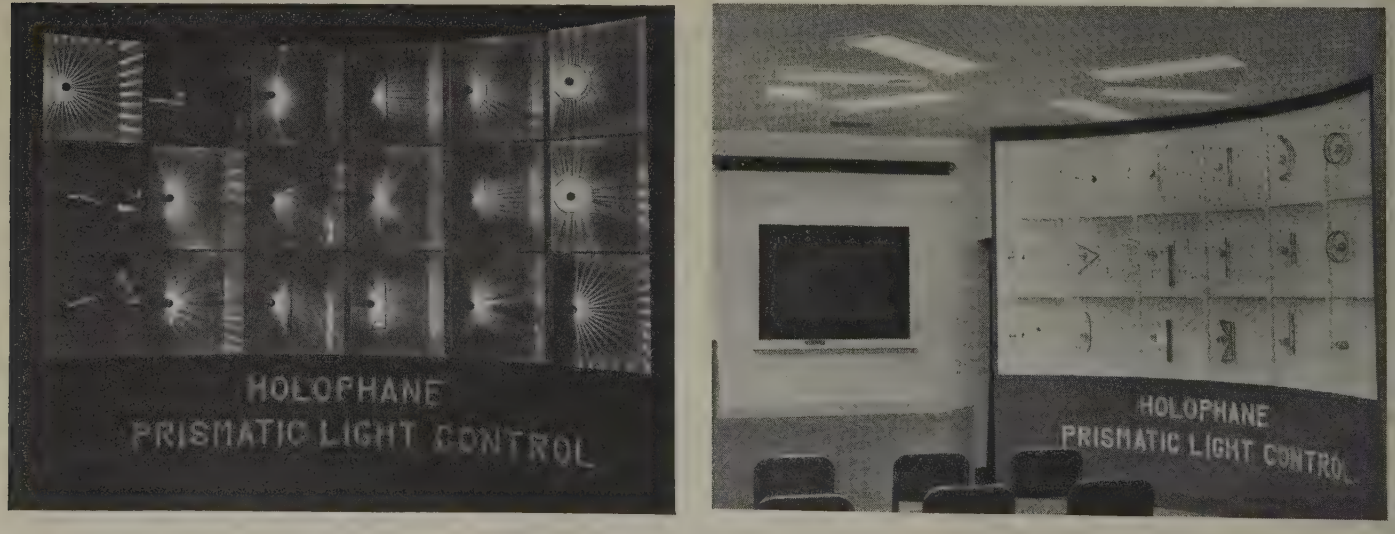
Alternate solutions for a lighting problem that are proposed can be demonstrated, compared, and evaluated on scientific grounds. Special demonstrations can be set up in the removable panel section of the ceiling for individuals or groups, and many of the 118 refractors and 80 lenses are on the shelves, available for personal handling and inspection. Informal or formal lectures can be arranged for groups on illuminating engineering subjects, or on lighting applications. Lighting schools also can be set up for groups to cover a day or more, with the curricula designed to fit the needs of the group.

The Home Lighting Corner, which is separate from the Light and Vision Institute, is set up to demonstrate engineered lighting in the home. Equipped as a combination living and dining room, the lighting demonstrations include recessed mantel lighting for accent and decorative effects; ceiling-recessed wall lighting for pictures, tapestries, or other wall ornaments; ceiling-recessed dining table lighting; top-recessed, plus bottom-recessed lighting, independently controlled, for glass and china cabinets.

The emphasis is on practical, efficient, pleasant, and comfortable lighting for living purposes, rather than on sensational effects of striking but limited application.

Every space in the executive offices has been illuminated so as to serve as an example of advanced lighting practice to visitors. The range of types of equipment in use and lighting levels available for inspection are: Home Lighting Room—recessed, flush incandescent, direct, 40 foot-candles; Treasurer's Office—suspended incandescent, indirect, 50 foot-candles; Bookkeeping Department—ceiling attached, semidirect, fluorescent, 60 foot-candles; Reception Room—recessed flush, fluorescent, direct,

* Registered trade-mark.



The optical control of light is demonstrated by the Prismorama* which forms a wall of the Light and Vision Institute (left). The unlit light control board and the major surgery lighting demonstration are shown at right

70 foot-candles; General Office—ceiling attached, semidirect, fluorescent, 80 foot-candles; Engineering Department—ceiling attached, semidirect, fluorescent, 90 foot-candles; President's Office—recessed, flush fluorescent, direct, plus recessed flush incandescent, direct, on working table, 100 foot-candles; desk, 75 foot-candles, secretary's desk, 45 foot-candles; Research Office—ceiling attached, 12 feet long fluorescent, instant-start, direct, 110 foot-candles.

Improved Telephone Relays Speed Dial System Service

A radical improvement in the dial telephone system's tiny "brain cells," the high-speed switches which can pick out the dialed number from among thousands of connections in the telephone network, has been made by the Bell Telephone Laboratories, research and development organization of the Bell System.

The new switches, or relays, can operate in less than 3/1,000 of a second, and can control as many as 24 different functions at the same time. They are faster, more sensitive, easier to manufacture than older types, and have a life expectancy of one billion operations, equivalent to one operation every second for more than 30 years.

Relays are sets of tiny switches controlled by an electromagnet. In response to electrical impulses from a telephone dial, they guide a call through the nerve centers of the dial system, see that the desired number is rung, and keep the telephones connected until the call is over.

In a modern dial office in a large city, more than a thousand relays are needed for each telephone call. Relays are also the basic parts of some kinds of mathematical computers, and of the new customer long-distance dialing system being tested in Englewood, N. J., which enables subscribers in that city to dial directly some 11,000,000 telephones in various parts of the United States.

For many years relays usually have consisted of narrow strips of flat spring metal assembled in layers about an electromagnet. The magnet causes the contact points of the metal strips to come together or to separate so that circuits are either closed or opened, as may be desired.

In the new relays, electrical and mechanical principles of operation have not been changed, but lengths of round spring wire are used instead of flat metal strips. These wire springs are held securely and accurately in place by a plastic block into which they are molded. Gone are a number of parts and all screws which held the old-style relay together. As a result, the number of parts has dropped from more than 70 to as few as a dozen.

Because of the molded construction, the new type of relay will be less expensive to manufacture and easier to assemble and adjust. It also has much greater operating efficiency and longer life than the flat spring variety, is easier to maintain, and requires less power to operate. Moreover, its operation is more than twice as fast as the principal types it replaces. Because of this greater speed of the wire spring relays, dial telephone exchanges may be designed using fewer relays than formerly.

A major problem Bell engineers had to overcome was the need to measure exactly, and at very high speed, various factors in a relay's operation. For one type of measurement they adapted a machine usually used to make high quality sound recordings; for another they developed a machine which could measure magnetism at intervals of 25 millionths of a second.

The sound recording machine was used because its motion could be controlled accurately to fractions of a thousandth of an inch. With the recorder, engineers tested for the amount of wear each part could withstand, and thus learned of the need to limit rubbing motion between parts to a thousandth of an inch or less if long life were to be obtained. Considered in terms of an expected life of one billion operations, the tiny motions equal about 30 miles.

Dewpoint Recorder Monitors Moisture in Wind Tunnel

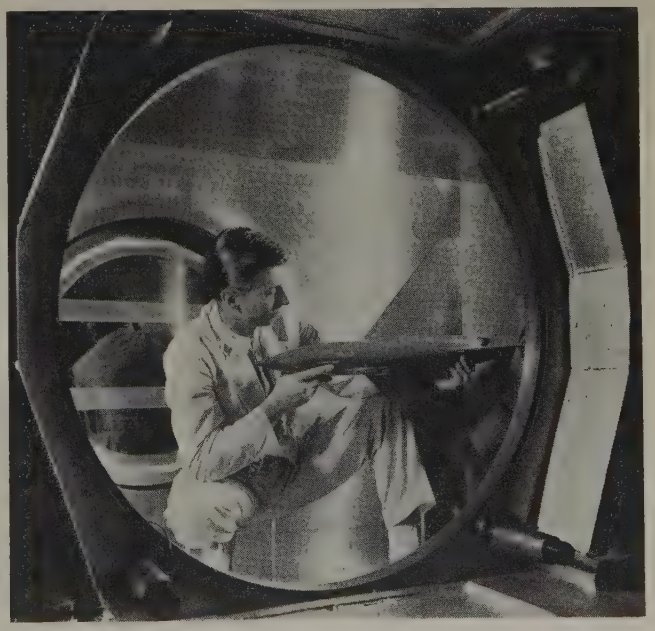
Aerodynamic research on supersonic aircraft and guided missiles is being aided by a dewpoint recorder installed by the National Advisory Committee for Aeronautics (NACA) in one of the nation's largest supersonic wind tunnels at Langley Field, Va.

The instrument, which automatically and continuously measures and records dewpoint temperatures, helps NACA engineers guard against the condensation of moisure which causes flow disturbances in the test section of the 4- by 4-foot supersonic pressure tunnel.

In attaining velocities up to twice the speed of sound, the air in the test section expands rapidly. This causes a sharp drop in temperature to values of −100 degrees Fahrenheit or lower, depending on operating conditions. Moisture condensation in the test section tends to go up in proportion to the drop in temperature. To guard against this, the recorder is used to monitor the tunnel air to determine the rate at which dry air must be bled into the tunnel to keep the moisture content low enough to avoid excessive condensation.

In addition to monitoring the moisture with an accuracy of ±5 degrees at −90 degrees Fahrenheit, the instrument gives an automatic and continuous record which can be kept permanently. It shows broad trends better than any spot-checking equipment.

The complete dewpoint recorder at Langley Aeronautical Laboratory is enclosed in a single floor-mounted steel cabinet. It consists basically of a temperature recorder, a



An engineer of the National Advisory Committee for Aeronautics, Langley Field, Va., inspects a test missile inside the NACA's 4- by 4-foot wind tunnel

Future Meetings of Other Societies

American Gas Association. Annual Convention. October 27–30, 1952, Atlantic City, N. J.

American Gear Manufacturers Association. Semi-annual Meeting. October 27–29, 1952, Edgewater Beach Hotel, Chicago, Ill.

American Society for Testing Materials. St. Louis District. October 30, 1952, St. Louis, Mo.

American Welding Society. National Fall Meeting. October 19–24, 1952, Bellevue-Stratford Hotel, Philadelphia, Pa.

Compressed Air and Gas Institute. October 8–10, 1952, Shawnee Inn and Country Club, Shawnee-on-Delaware, Pa.

Eastern Electrical Wholesalers Association. National Electrical Industries Show. October 21–24, 1952, 69th Regiment Armory, New York, N. Y.

Hydraulic Institute. October 22–24, 1952, Edgewater Beach Hotel, Chicago, Ill.

National Association of Corrosion Engineers. South Central Region. October 1–3, 1952, Jung Hotel, New Orleans, La.

National Association of Electrical Distributors. Fall Meeting, Pacific Zone. October 6–8, 1952, Hotel del Coronado, Coronado, Calif.

National Electrical Contractors Association. Annual Convention. October 6–10, 1952, Hotel Morrison, Chicago, Ill.

National Electronics Conference. Eighth Annual Conference. September 29–October 1, 1952, Sherman Hotel, Chicago, Ill.

National Farm Electrification Conference. October 20–21, 1952, Hotel Statler, Detroit, Mich.

National Safety Council. 40th National Safety Congress and Exposition. October 20–24, 1952, Chicago, Ill.

Radio Television Manufacturers Association Fall Meeting. October 20–22, 1952, Hotel Syracuse, Syracuse, N. Y.

Society for Non-Destructive Testing. Twelfth Annual Meeting. October 20–23, 1952, Hotel Sylvania, Philadelphia, Pa.

gas chamber, an electronic unit, a 2-stage refrigeration system, controls, a chamber light source, and phototubes.

Air, pulled in from the wind tunnel, goes through the gas chamber and over a refrigerated mirror which is located in a phototube system. Moisture in the air forms a dew spot on the mirror and a resulting decrease in reflected light which is measured by the phototubes. Signalled by the phototubes, the refrigeration is regulated to maintain the mirror at a temperature which will permit a dew spot to form but not to grow. This temperature, the dewpoint temperature, is transmitted to the recording unit by a thermocouple mounted directly on the mirror.

Elevator Door Safety Device Speeds Passenger Service

An electronic door safety shoe has been developed by the Otis Elevator Company to meet the need created by automatic, operatorless elevators in commercial office buildings for a safety device that would stop or reverse a closing door if a passenger got in the way, and at the same time would not unduly slow down service. This safety shoe operates on a principle similar to that used in the proximity antiaircraft artillery fuse developed during World War II.

Mounted on the elevator car door, the safety device has a "field of influence" which extends almost the full height of the car and hoistway doors and for an adjustable distance in front of them. If anyone enters this field when the doors are closing, they promptly stop and slide back. The doors will respond whether an adult or a child enters the field of influence.

If the doors are just beginning to close, however, and a passenger enters the doorway beyond the field of influence of the safety shoe, the doors will continue to close. Being able to distinguish between obstructions near the doors and those at a safe distance, the electronic safety shoe protects passengers without unnecessarily slowing down door closings. Its ability to judge distance in front of both car and hoistway doors makes possible safe and fast door operation in automatic elevators.

American Engineers Attend IEC Meetings in Netherlands

An American delegation of 16 technical experts in the field of electrical engineering attended Council and technical committee meetings of the International Electrotechnical Commission (IEC) in Scheveningen, Netherlands, September 3–13, 1952.

Dr. H. S. Osborne, president of the United States National Committee (USNC), R. C. Sogge, vice-president, USNC, and J. W. McNair, secretary, USNC, attended meetings of the Council and the Committee of Action.

The United States had representation on 13 of the technical committees. The committees, covering such aspects of electrical engineering as rotating electric machinery, graphical symbols, radio, power switchgear, power rectifiers, co-ordination of insulation, and dry cells and batteries, are working on various phases of the standards, specifications, and methods of tests in their respective fields.

The IEC was formed as a permanent body in 1904 and in 1947 became affiliated with the International Organization for Standardization as its electrical division. The National Committee of 26 countries comprise the membership of the Commission.

Members of the American delegation were R. S. Burnap (M '29), Radio Corporation of America; V. L. Cox (F '50), General Electric Company; V. M. Graham (M '47), Sylvania Electric Products, Inc.; M. S. Hancock (F '50), Westinghouse Electric Corporation; M. H. Hobbs (F '48), Westinghouse Electric Corporation; J. W. McNair (AM '25), American Standards Association; L. W. Morton (M '45), General Electric Company; H. S. Osborne (F '21), American Telephone and Telegraph Company; Leon Podolsky (M '45), Sprague Electric Company; E. F. Seaman (M '43), Bureau of Ships, United States Navy Department; A. H. Scott (M '48), National Bureau of Standards; P. C. Smith (M '48), Westinghouse Electric Corporation; R. C. Sogge (M '35), General Electric Company; O. B. Vikoren (M '43), Philadelphia Electric Corporation; C. F. Wagner (F '40), Westinghouse Electric Corporation; and H. P. Westman (M '46), International Telephone and Telegraph Company.

New Generating Plant Under Construction in N. J.

Construction is progressing rapidly on the new generating plant of Public Service Electric and Gas Company, Newark, N. J., adjacent to its present Kearny (N. J.) Generating Station. The construction schedule calls for the completion of the first unit before the end of this year, and the second unit by next spring. This additional capacity will nearly double the capacity installed at Kearny, and will make it the largest generating station in the Public Service system.

The installation consists of two 145,000-kw turbine-generators, larger than any units of this type now in service. Each turbine will be supplied by high-pressure high-temperature steam at 2,350 pounds per square inch, 1,100 degrees Fahrenheit, and 1,050 degrees reheat, by a single boiler capable of evaporating 525 tons of water per hour. These boilers will use the principle of pumped circulation of the water through the steam-producing tubes. This is one of the first installations of this design in this country, although installations of smaller capacity have been used in Europe for many years. Each boiler will be equipped to burn either pulverized coal or oil, and will consume about 1,200 tons of coal or 5,200 barrels of oil daily.

Each turbine-generator will be over 103 feet long, and will weigh more than 700 tons. The rotating part of the machine will weigh approximately 100 tons, and while turning at the normal speed of 3,600 rpm, the tips of the low-pressure turbine blades will be traveling at a speed of 950 miles per hour. The electric energy generated will be at 20,000 volts.

Many new design features have been incorporated in the layout of the station which have reduced considerably the size of the installation. The new machines will be supervised independently from a separate control room, from which all main and auxiliary equipment will be operated. The efficiency of the new installation will be greater than that of the present station.

The output of the generators will be carried through four large 3-phase transformers and underground oil-filled pipe-type cable to the 132-kv outdoor substation.

The Gift of Engineering

In the Beginning only Divine Force could have guided creation of the Universe and the evolution of life on Earth. All creatures endured the forces of nature until the mind of man matured. Then man's desires sought satisfaction by invention of tools to strengthen his hand. But tool making brought civilization with collective cares outreaching the ability of arms even when aided by the lever and wheel. Slowly our forebearers began to discover natural laws that explained the drawing of power from falling water, wind, and steam. It was only in our fathers' time that electricity on wires, and then on wireless waves encircled the earth, yet *we* have cradled atomic change and released the latent energy that lights the stars, thereby threatening the existence of our enemies and of our own children. It is the engineer's destiny to control and direct power in order to "provide for the common defense, promote the general welfare," and so to help "secure the blessings of liberty to ourselves and our posterity."

As an engineer you are given a favored part in this great design; without you the plan would be less perfect. When you build a bridge, design a dam, perfect a process, or link power lines together you play a role in the achievement of human destiny. You therefore owe everything that you have to give in honest and sincere effort toward engineering progress. Dishonesty is inconceivable in even the smallest detail of a professional mission. Carelessness and sloth are but little less reproachable. Integrity and energy deepen the luster placed upon the profession of engineer by the master builders of the past. Disclosure of advances must be given freely to aid in educating the engineers of the future. Thus with each generation rising above the teaching of its forerunner, progress by employment of science is the gift of engineering to mankind. With this gift must go the engineer's unending effort that ethics may mark its use and morality remain its master.—*L. E. Grinter, Vice-President, American Society for Engineering Education.*

New Computer Able to Do 100,000 Additions a Second

A high-speed electronic computing machine capable of 2,000 multiplications, 1,200 divisions, or 100,000 additions a second was unveiled recently by the Institute of Advanced Study, Princeton, N. J.

Scientists at the institute have been at work on the machine for the last 6 years, testing it and adding refinements which have enabled the computer to lead the way to the development of the complex "electronic brain" of today. It has served as the prototype for similar computers.

Undertaking such a project was a departure for the institute, which is primarily a haven for pure thought and theory as opposed to experimentation in specific fields. The development was originally begun at the request, and under the sponsorship, of the Research and Development Service of Army Ordnance, which sought a machine to solve its ballistics problems. Later the United States Navy, the Air Force, and the Atomic Energy Commission joined in.

The key development which has so greatly increased the scope of computing machines in the last few years is the improvement of the so-called "memory" organ, through which thousands of answers to intermediate steps of the problem are stored until needed in another step. It makes possible solutions of problems so protracted that they would not have been worth tackling a few years ago.

For example, the machine has been used to test the conjecture of the 19th century mathematician, E. E. Kummer. Kummer tested his theory with half a dozen equations, which took him 6 months. The machine charted out on a million in 6 hours, plus several weeks of preparation of data on punched tape to be introduced into the machine.

This sort of thing is one of the most important implications in the new computers. Problems which seem interesting to scientists but which formerly were impossible for practical reasons now can be undertaken with this new tool, thus widening the range of scientific investigation.

National Science Foundation Announces 1953–54 Fellowships

The Second Graduate Fellowship Program of the National Science Foundation (NSF), providing awards for study during the 1953–54 academic year in the mathematical, physical, medical, biological, and engineering sciences, has been announced.

The majority of awards under the 1953–54 program will be made to graduate students seeking master's or doctor's degrees in science, although a limited number of awards will be made to postdoctoral graduates. NSF graduate Fellows are selected solely on the basis of ability. Candidates will be judged on their scientific aptitude and achievement as reflected in academic records and recommendations from individuals who are familiar with their scientific aptitude. Predoctoral applicants will take an examination designed to measure scientific promise and level of advancement.

Application forms for both predoctoral and postdoctoral fellowships for the 1953–54 academic year may be obtained after October 1, 1952, from the National Science Foundation, Washington 25, D. C. Completed applications must be returned to the Fellowship Office, National Research Council, by January 5, 1953. The special examination for predoctoral candidates will be given at various places throughout the United States on January 31, 1953.

Applicants will be screened by panels of outstanding scientists chosen by the National Academy of Sciences. Final selection will be made by the National Science Foundation. No awards will be made for study in clinical medicine, although awards will be made to medical students interested in careers in medical research.

NSF graduate Fellows may attend any accredited institutions of higher education in the United States or abroad. Stipends will vary with the academic status of the Fellows.

Electronic Project Simplification Urged by Bureau of Ships

The increasing complexity and resultant increased maintenance and reduced reliability of electronics equipment is a matter of great concern to the Bureau of Ships. Every effort is being made by the Bureau of Ships to simplify the design of electronics equipment. To accomplish this objective successfully, the full co-operation of the engineering staffs of all Bureau of Ships contractors is needed.

The Bureau of Ships solicits and will welcome proposals from contractors which will result in the production of less complex and more easily maintained equipment. Such proposals for simplification of designs are desired any time during the performance of existing contracts and will be evaluated on a not-to-delay production basis. It is understood that under no circumstances shall changes be invoked in existing contracts unless authorized by formal change under the contracts.

In order to insure proper evaluation by the Bureau of proposals for simplification of design, it is requested that the proposal completely set forth any existing specification requirements which cannot be fully met. Such proposals also should recommend specification changes which will be necessary to accomplish the proposed simplification.

Proposals for simplification of designs on existing contracts should be forwarded to Bureau of Ships, Electronics Design and Development Division, Code 810, Washington 25, D. C.

Scientists Open New Fields for Indian Industry and Research

Chemists at the National Chemical Laboratory, Poona, India, are putting science to work to open new fields for Indian industry. The laboratory, under the direction of Professor J. W. McBain of Stanford University, was opened 2 years ago as the first of a chain of national research centers which India is building.

One large room of the laboratory has been turned into a miniature factory where research workers test industrial processes to determine whether they are economically feasible. One of their main objectives is to find a use for India's excess supply of chlorine and, in their search, they have turned to another surplus product, rubber waste.

In the physical chemistry section, laboratory workers are producing gelatin from hides and bones and using it to manufacture photographic emulsions to enable India to produce her own photographic film.

Chemists are using Indian asbestos to make car battery containers. They are transforming neem seeds (seeds of Indian lilac trees) into soap, oil, and pharmaceutical products. They have opened a clinic for small businessmen manufacturing chemical products and are using micro-organisms to attempt to solve India's sulphur shortage.

One of the more interesting experiments is the extraction of castor oil from the castor seed. At present Indian villagers must sell their seed to a mill where the oil is pressed out in a pure enough form for commercial use. Chemists remembered that for centuries Indian farmers have extracted the oil merely by heating the seeds. This process yields oil of varying quality which can be used only at home and cannot be marketed. However, by controlling this heating, oil of commercial quality can be produced with nothing more complicated than a fire and a pan. Villagers could set up this simple heating apparatus and run it themselves through a co-operative, enabling farmers to obtain a better price for their oil than if they had sold their seeds to a mill.

New Electronic Tube Permits Single Antenna Beacon Radar

Development of a new electronic tube, which makes possible for the first time the operation of a beacon radar from a single antenna, was announced recently by Sylvania Electric Products, Inc. Previously, reliable beacon operation required the use of two separate antennas, one for receiving and one for sending.

The new tube, an instant firing tube designated as type *6214*, will permit the manufacture of more compact and less costly beacon radar equipment. Beacon radar has become an important factor in aerial and nautical navigation. A beacon receives a radar signal from an approaching airplane or ship and transmits an answering signal which has a recognizable coded characteristic. The airplane or ship is able to determine both direction and range to the beacon, located at a known point convenient for navigation aid.

Type *6214*, developed to meet the special requirements of beacon radar, is capable of instantaneous operation of the first pulse of a coded system of pulses. Conventional anti-transmit-receive (ATR) tubes often fail to operate immediately when the transmitter starts, thus preventing proper transmission for this period of time, possibly as long as several seconds. Therefore, beacon systems have been engineered without ATR tubes, making two antennas necessary. With an instant-starting ATR tube now available, a single antenna will handle both the receiving and sending functions.

The instant starting feature of the new tube has been achieved by adding an ignitor electrode to the end plate of the tube. The

power supply for this ignitor is taken from the supply for the TR (transmit-receive) tube ignitor.

The TR tube and its companion the ATR are used principally as automatic electronic gates or switches in radar sets. They permit the set to use the same antenna for transmission and reception; protect the ultrasensitive receiver from damage from the high instantaneous power of the transmitted signal; and prevent dissipation of the weak reflected signal in the transmitter during reception time.

University Center Will Aid Mexican Scientific Advancement

A new university center, the Ciudad Universitaria, is being constructed outside Mexico, D. F., Mexico, which is expected to contribute greatly to scientific, educational, and cultural advancement in Latin America.

The center will possess the first atom disintegrator in Latin America. It will be part of the equipment in an Institute of Nuclear Physics where scientists will conduct research designed to discover new peacetime uses for atomic energy. The University of Massachusetts has loaned a neutron measuring unit for the Hall of Cosmic Rays.

The university will include schools of economics, law, philosophy, commerce, engineering, architecture, medicine, dentistry, and chemistry.

Proceedings of ICI Convention Available From U. S. Committee

The Proceedings of the 1951 Stockholm Convention of the International Commission on Illumination (ICI) are available from the United States National Committee of the ICI. These records of papers and secretariat reports comprise two bound volumes containing nearly 1,500 printed pages. Contributions are by outstanding scientists and engineers in this field from every member country.

The ICI Proceedings embrace international concepts, opinions, findings, and developments in the lighting field. They are available at a delivered price of $12.50 per set. Orders should be sent to T. D Wakefield, Treasurer United States National Committee, ICI, care of F. W. Wakefield Company, Vermilion, Ohio.

Teaching and Research Awards Available Under Fulbright Act

Announcement has been made of Fulbright awards for University Lecturing and Advanced Research for the academic year 1953–54 in Europe and the Near East and in Japan, Pakistan, and the Union of South Africa. Countries interested in electrical engineering lecturers are France, at the Faculty of Science, Nancy, and Pakistan, at the University of Peshawar.

Copies of the announcement, as well as general information about the program, are available upon request to the Conference Board of Associated Research Councils, the Committee on International Exchange of Persons, 2101 Constitution Avenue, N. W., Washington 25, D. C. Application forms are supplied upon the request of individual applicants to the committee, and upon completion should be returned to the committee. To be accepted in the current competition they should be postmarked no later than October 15, 1952.

Course in Isotope Techniques to Be Given at Oak Ridge

A course on advanced radioisotope techniques in biochemical research will be given by the Special Training Division of the Oak Ridge (Tenn.) Institute of Nuclear Studies from November 3–14, 1952.

The first week of the course will be devoted to techniques centering around the use of Carbon 14. The second week will be concerned with the other major isotopes used in biochemical research.

Applications must be filed by October 1, 1952. Application blanks and other information may be obtained from Ralph T. Overman, Chairman, Special Training Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tenn.

Westinghouse Establishes New Fellowship Fund

A fellowship fund to help promising young engineers and scientists of the Westinghouse Electric Corporation continue their studies at a graduate level has been established in honor of the late Leon R. Ludwig, inventor and Westinghouse engineering executive. The fund was established by Mr. Ludwig's widow and daughter at the time of his death in 1951.

A group of five Westinghouse officers will administer the fund and will be responsible for the selection of candidates for postgraduate study from among outstanding young Westinghouse engineers.

To be eligible for a fellowship, a candidate must have shown marked ability in engineering or scientific fields and must be a Westinghouse employee of at least 2 years' service.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Servomechanism Design

To the Editor:

I wish to submit the following comments on the article by Howard Hamer entitled "Linear Circuit Theory and Servomechanism Design" (*EE, Jul '52, pp 614–15*).

Mr. Hamer's definition of a servomechanism as being distinguished from other electromechanical systems by the use of feedback to increase accuracy, indicates that he is primarily oriented in his thinking toward "instrument servomechanisms." There are many servomechanisms which are not electromechanical. This is particularly true in the industrial control field. There are also many servomechanisms where feedback is not employed to increase accuracy, but rather to permit the use of less expensive and more reliable power amplifiers.

Perhaps the best definition of a servomechanism is that proposed by Hagen.[1]

Mr. Hamer's brief history of the development of the servomechanism design art leaves an erroneous impression concerning the turning point from basic linear design theory development to refinement of said basic theory. Certainly "The Analysis and Synthesis of Linear Servomechanisms" by A. C. Hall in 1943* contained the complete outline of the frequency-response technique of servomechanism design. The use of logarithmic co-ordinates was added by workers at Bell and was first reported in detail by James, Nichols, and Philips.[2] Thus, while Brown and Campbell's book[3] was the first complete textbook on the subject of servomechanism design theory, Dr. Hall's work covered the entire basis of the refined techniques which followed.

In the paragraph beginning "The closest we have come..." (*p 615, col 1*), Mr. Hamer has suggested that the analogue computer technique of servomechanism synthesis is a poor compromise with a yet-to-be-found but to-be-hoped-for slide-rule solution of servomechanism synthesis.

The analogue computer is not a "last resort" of design engineers. It represents, rather, the finest form of synthesis procedure for it minimizes the number of linearizations which must be made in the system analysis. Furthermore, it permits of a detailed study of the system form to arrive at an optimum design with a speed and economy not to be matched by any hand techniques. The vast growth of the use of analogue computers by all fields of engineering design bears witness to the number of problems which were inadequately handled by previous techniques.

Mr. Hamer seems to have confused the "breadboard" step in design with his disparagement of the analogue computer. While the analogue computer minimizes the need for breadboard studies of a system, it cannot eliminate it entirely until our ability to represent the components of a servomechanism improves. This is rapidly approaching; but until such practical details as to whether a particular gear train will wear out too readily, an amplifier develop unusual

*Employing Bode's work from *Bell System Technical Journal*, volume 19, July 1940, pages 421–54.

large error characteristic, and so forth, can be eliminated, the breadboard step will be a desirable intermediate design stage.

Finally, Mr. Hamer suggests that "servomechanism designers look with envy upon their fellow engineers who are engaged in the design of purely electronic systems, because the state of the art is such that a good paper design of a vacuum-tube circuit has a good chance of working properly the first time it is put together (computer amplifiers excepted)." If you consider any application of an electronic circuit requiring accuracy comparable to an instrument servomechanism, it is not straightforward to design. Every sort of nonlinear tube performance must be taken into account and all of the secondary effects included if the high performance is to be realized.

The state of the art of servomechanism design is such now that for an application requiring good performance which can use standard components with no more than three feedback quantities, the synthesis process is straightforward. The nonlinear aspects of the components can be accounted for in the approximate fashion which such second-order effects warrant. The breadboard of the system will need at most minor modification to meet the specifications.

When, however, extremely high performance is required, when the capability of every component is being pushed to the limit, and when other specifications of size, temperature, and so forth, are extremely tight, then extensive redesign at the breadboard level may be required. If the design previously has been checked on an analogue computer and proved satisfactory, the breadboard modification will be reduced to bringing the characteristic of some component which the computer could not adequately simulate into line.

Rather than adopt such a pessimistic attitude toward servomechanism design, let us be proud of the speed with which this field has risen from its infancy to its present status. The success with which its principles have been applied to analogue computers, gun-fire control systems, industrial controls, automatic machine tool, process controls, and so forth, demonstrates the strength of the procedures developed to date and the breadth of vision of the men responsible for their development.

A. M. FUCHS (AM'51)

(Eclipse-Pioneer Division, Bendix Aviation Company, Teterboro, N. J.)

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2. Theory of Servomechanisms (book), **James, Nichols, Philips.** McGraw-Hill Book Company, Inc., New York, N. Y., 1947.

3. Principles of Servomechanisms (book), **G. S. Brown, D. P. Campbell.** John Wiley and Sons, Inc., New York, N. Y., 1948.

Railroad Electrification

To the Editor:

I wish to make a few remarks on the recent article by J. C. Aydelott, entitled "Impressions of European Railroad Electrification" (*EE, June '52, pp 497–501*).

There seems to be considerable interest in electric traction systems using industrial frequencies (50–60 cycles per second) throughout the world. In the past 2 years the leading electrical engineering journals of the United States, Germany, France, Switzerland all carried articles on such systems and associated problems. The shift of emphasis towards traction systems of industrial frequency is chiefly due to the tendency towards improved economy in trolley copper and improved voltage drop ahead of the locomotives and the desire to integrate the railway as a consumer into the national power system.

There are three fundamentally distinct types of motors used in industrial frequency electric traction:

1. Single-phase series commutator motors in connection with a transformer.
2. Three-phase induction motors in connection with phase and frequency converters.
3. D-c motors: (*a*). in connection with mercury-arc rectifiers; (*b*). in connection with rotary converters.

The main strength of recent 50-cycle series motors is in the higher speed ranges. They are rather delicate regarding commutation in the lower ranges. The d-c motors offer unsurpassed adaptability to various operating requirements.

The investigations of the French Railways have shown the following results with respect to efficiency and power factor:

Efficiency: 1. rectifier type; 2. 50-cycle series type; 3. phase- and frequency-converter type; 4. rotary converter type.

Power factor: 1. phase- and frequency-converter type; 2. rotary converter type; 3. 50-cycle series type; 4. rectifier type.

Judging from the point of view of efficiency and power factor and maintenance, the solution with phase and frequency converters seems to offer the best compromise.

F. Nouvion, of the French Railways, in his recent paper on single-phase traction, takes the opportunity to salute the memory of the great engineer Koloman de Kando, a pioneer in the field of electric traction. It is little known generally that a very successful locomotive, based on De Kando's ideas, has been developed quite recently; the 3,200-horsepower multipurpose locomotive built by Ganz and Company of Budapest, Hungary. In accordance with modern trends, apparent both in America and Europe, an axle arrangement B-C has been chosen. The locomotive weighs 186,000 pounds in running order and is rated at 3,200 horsepower for 1 hour. The trolley wire carries 50-cycle 15-kv alternating current. This energy is converted from single phase to 3 phase by means of a synchronous phase converter and is fed into an induction-type frequency converter, both mounted on the locomotive. The 3-phase induction motors, each driving one axle, are fed through the latter. Five running speeds are provided, each fairly well fixed by the shunt characteristic of the

Table I

Locomotive	Relative Tractive Effort (Tractive Effort/Weight on Drivers) in Per Cent Approximate Values				
Ganz B-C 3,200 horsepower (1-hour rating) phase- and frequency-converter type, 50 cycles per second	16.1	16.1	12.8	10.2	8.3
Oerlikon B-B 2,400 horsepower (1-hour rating) series commutator type, $16\frac{2}{3}$ cycles per second, express	14.6	13.2	14.2	12.7	9
Oerlikon 1-D-1 4,500 horsepower (1-hour rating) d-c type	15.5	15.5	9.9	5.3	12.5
General Electric B-B 2,500 horsepower (continuous rating) series commutator type, 25 cycles per second	14.2	13.4	9.2	7	
Westinghouse 2(B-B-B) 6,000 horsepower (continuous rating) ignitron type	18	10.2	7.6	5.2	
English Electric C-C 1,600 horsepower diesel-electric type (continuous rating)	9.9	5.8	3.9	3	2.5
	Speed (Miles Per Hour)				
	15.5	31	46.5	62	77.5

Table II. The B-C Locomotive of Ganz and Company

	Speed (Miles Per Hour)				
	15.5	31	46.5	62	77.5
One-hour rating, horsepower	1,250	2,500	3,000	3,200	3,200
Tractive effort (1 hour) pounds	30,000	30,000	23,800	19,000	15,300
Tractive effort (maximum) pounds	46,500	46,500	52,500	26,600	21,200

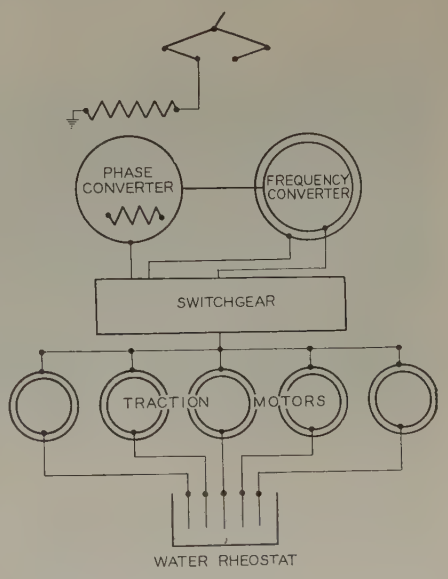

Figure 1. Schematic diagram of Ganz B-C phase- and frequency-converter locomotive

induction motors. Smooth start and transition from one speed to another is obtained by a water rheostat inserted into the rotor circuit of the driving motors. Favorable starting effort is obtained by raising the voltage on the terminals of the driving motors for a short duration. Although the efficiency of this locomotive, as a result of the frequency converter, is slightly inferior to that of other modern types, this factor is more than balanced by the lower current demand due to the phase converter allowing operation at unity power factor. Designed for both passenger and freight service, the B-C locomotive is capable of developing 16 per cent of its weight as tractive effort in the lower speed ranges and to utilize its full 3,200 horsepower in the higher speed ranges.

Tables I and II offer favorable comparisons with other modern electric locomotives of American, Swiss, and British origin, regarding relative tractive effort (weight on drivers/tractive effort)$^{-1}$ and speed.

J. R. M. SZOGYEN

(English Electric Company of Canada, Ltd., St. Catharines, Ontario, Canada)

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8. *Elektrotechnische Zeitschrift* (Berlin, Germany), volume 73, number 8, pages 119–21.

Kirchhoff and Thevenin's Theorem

To the Editor:

It is now fairly well known that Thevenin's theorem was anticipated by Helmholtz[1].* The Helmholtz formulation included, as I pointed out a few years ago[2], even those extensions of the original theorem to networks with more than two terminals which have been suggested from time to time by later authors.

However, it is in the narrower field of 2-terminal networks that the theorem finds its principal application, and for this reason it may be of some interest that even Helmholtz has been anticipated to some extent by Kirchhoff, who in 1848 derived the following theorem[3]:

"Given a system of conductors consisting of two parts which are joined by two wires. Let these wires be cut and the system thereby divided into parts A and B. Let part A consist of a simple chain of bodies (that is, one where the first and the last body are in contact with only one, and every other body of the chain is in contact with only two neighbors). Then it is possible, without changing the flow of current in B in any way, to substitute for A a linear conductor, said conductor being the seat of an electromotive force equal to the sum of the voltage differences in A, and of a resistance which depends only on the shape and conductivity of the bodies of which A is constituted."

Since a network of linear conductors is a "body" in the sense of this theorem, Thevenin's theorem appears to be anticipated, were it not for the restriction that the electromotive forces in the system A are assumed to reside in the contact areas between the constituent bodies. This proviso appears in the accompanying text and in the proof which uses a chain of equations corresponding to the chain of constituent bodies. Thus, in the absence of B no currents circulate in the system considered.

This proof makes considerable claims on the mathematical maturity of the reader, and if we take into account that it deals only with a restricted form of the theorem we are probably not far wrong in assuming that it acted as an irritant on Helmholtz. It had the most fortunate effect, for it induced Helmholtz to present in this paper anew the principle of superposition—which had already been introduced into this field by other workers—and to elaborate its consequences in an accomplished form.

A. BLOCH

(Research Laboratories, The General Electric Company, Ltd., Wembley, Middlesex, England)

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2. Letter, **A. Bloch.** *Wireless Engineer* (London, England), 1943, page 194.

3. Ueber die Anwendbarkeit der Formeln fuer die intensitaet der galvanischen Stroeme in einem System linearer Leiter auf Systeme die zum Teil aus nichtlinearen Leitern bestehen, **R. Kirchhoff.** Poggendorff's *Annalen*, volume 75, 1848, pages 189–205; or "Collected Papers," pages 39–49.

Loom Desynchronizing

To the Editor:

I was very interested in the article on "Loom Desynchronizing" by F. D. Snyder (*EE, Aug '52, pp 719–20*) inasmuch as several years ago I was called in to design such a system for a loom in the eastern part of the province of Quebec. This work was done together with B. A. Berger, consulting mechanical engineer.

Basically the circuit was the same as that shown in Figure 2 of the article, except that the method of slowing down the fast motor was by means of two resistors, one in each leg of the 3-phase motor.

Although the method was proved practical, the system was not installed for this reason. There were about 600 looms involved, and at an estimated cost of $20 per double loom installed, the over-all cost of the system would run to $6,000. On the other hand, it was estimated that it would cost around $7,500 to reinforce the structure, and as in this instance there was quite a bit of land around and supporting buttresses could be installed simply, it was decided to proceed with the reinforcing.

One point that is not mentioned in the article is the fact that, inevitably, when the two horizontal forces are cancelled out, the vertical forces are doubled. Exact measurements were not made on the system, but it was quite interesting to note how the building in the vicinity of the pair of looms could be felt to have little horizontal motion, but the vertical motion was increased.

H. H. SCHWARTZ (AM '50)

(Electrodesign, Montreal, Quebec, Canada)

* The Helmholtz anticipation was pointed out in a "Letter to the Editor" from H. F. Mayer (*EE, Feb '50, p 186*).

NEW BOOKS

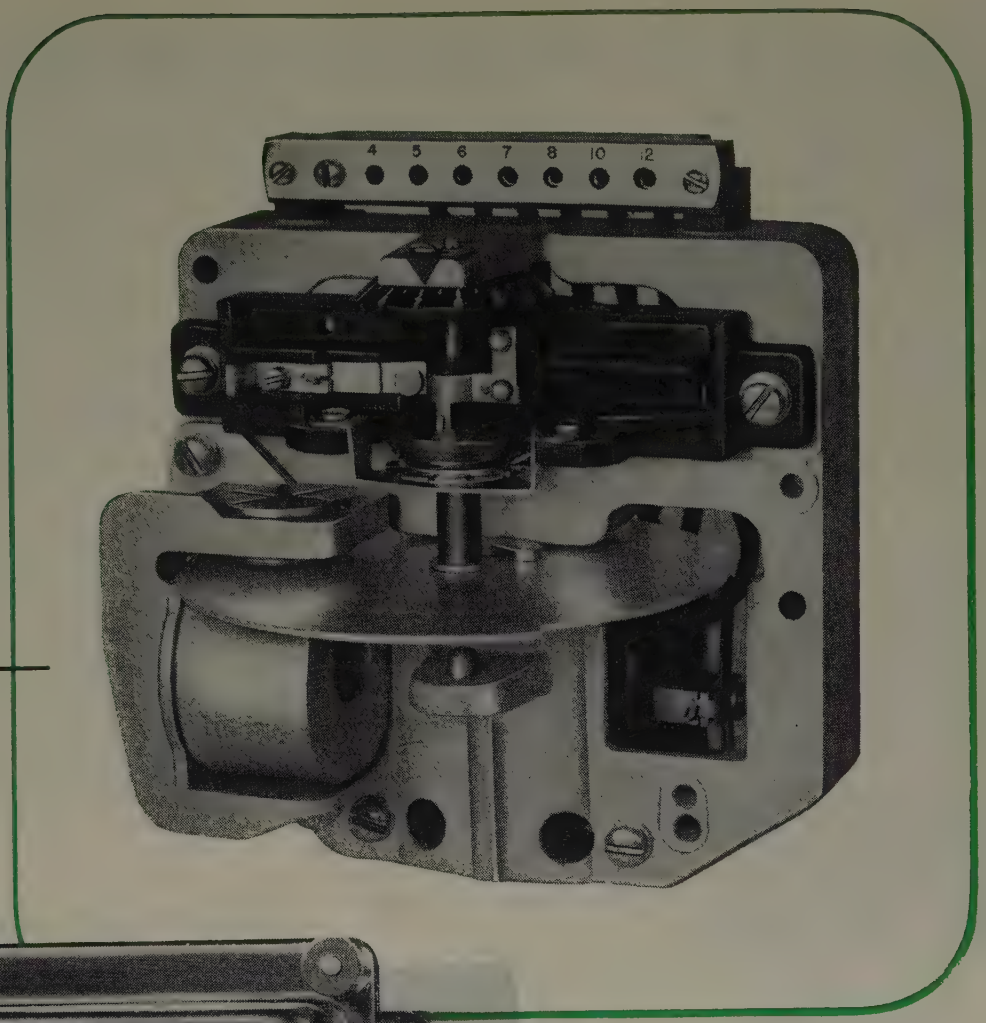
The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

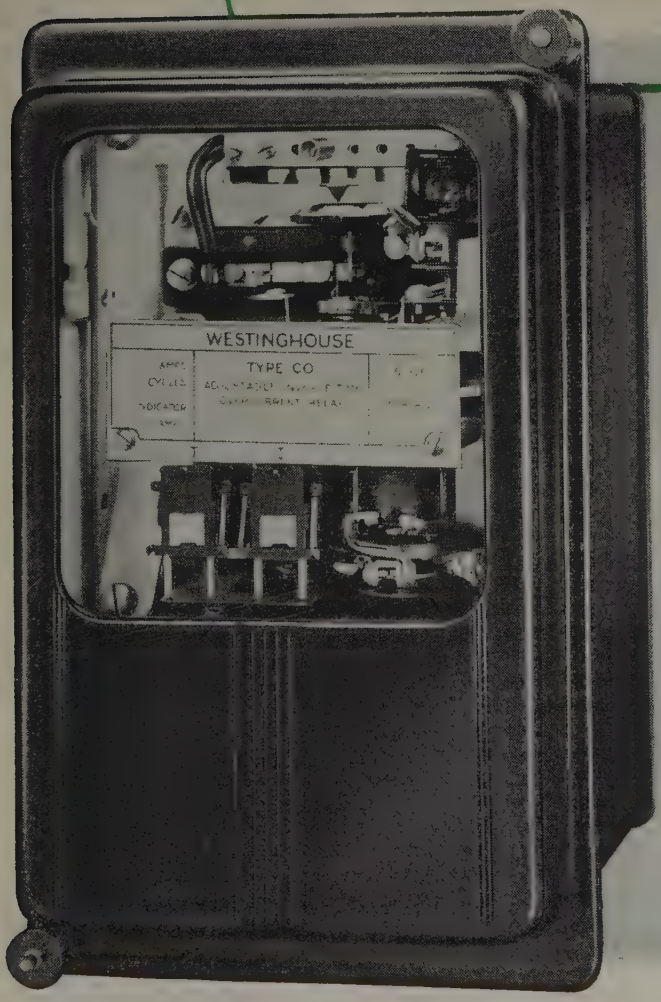
SAMPLING INSPECTION BY VARIABLES. By Albert H. Bowker and Henry P. Goode. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., first edition, 1952. 216 pages, tables, graphs, charts, 9¼ by 6¼ inches, bound. $5.50. This book presents a comprehensive set of sampling plans for use when inspection of the item is by variables and when the lot is to be evaluated in terms of its percentage defective. The plans may be used for both incoming and outgoing products and for goods in process. General principles, the construction of plans, and standard procedures are presented and detailed instructions are given for selection, installation, and operation. Illustrative examples and the necessary tables and charts for rapid application are included.

SMITHSONIAN LOGARITHMIC TABLES. To Base e and Base 10. (Smithsonian Miscellaneous Collections, Volume 118.) Prepared by George Wellington Spenceley and others. Smithsonian Institution, Washington, D. C., (publication 4054), 1952. 402 pages, tables, 9¼ by 6½ inches, bound. Both natural and common logarithms, in respective sections, are given for all integers from 1 to 10,000 to 23 decimal places. For dealing with numbers of more than four significant digits additional columns are included giving the logarithms for the second and third of the factors into which the number must be broken up. The method of using these in computation is explained in an introduction which also indicates how a fourth factor is dealt with in the case of greatly extended decimals, for instance.

STRAIN GAUGES. Theory and Application. By J. J. Koch and others. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, (available in United States, from Elsevier Press Inc., 402 Lovett Boulevard, Houston 6, Tex.), 1952. 95 pages, illustrations, diagrams, 8¾ by 6 inches, bound. $2.75. Prepared by the Netherlands Industrial Organization for Applied Scientific Research and the Philips Industries, this study is for the use of both technicians and students. It deals with the construction and use of strain gauges and measuring instruments for testing problems encountered in practical engineering and in the laboratory, and with the interpretation of values obtained. A chapter on stresses and the theories of failure is included.

THEORETISCHE ELEKTROTECHNIK. By Karl Kuhlmann. Volume III: Grundzüge der Theorie Elektrischer Maschinen. Verlag Birkhäuser, Basel, Switzerland, 1951. 547 pages, graphs, diagrams, tables, 9½ by 7 inches, bound. Sw. Frs. 74.90. Volume III of this 4-volume set presents an extended outline of the theory of electric machines. The main sections are as follows: production of magnetic fields; calculation of inductance of windings; induced electromotive force; magnetic energy and torque of electric machines; ohmic and iron losses; calculation by means of symmetrical components. The object of the book is to provide the basic theoretical knowledge required by every electrical engineer.





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INDUSTRIAL NOTES ....

RCA News. The development of the first very-high-frequency transistors, pointing the way to their application in television and frequency modulation radio, has been announced by the Radio Corporation of America. Several developmental point-contact transistors were made to oscillate at frequencies well up in the 100-to-200-megacycle band, and one reached a record high frequency of 225 megacycles per second. Prior to the recent experiments, transistors had been regarded as limited to relatively low-frequency applications.

Introduction of a new and longer playing 45-rpm record also has been announced by RCA. It will be known as the 45 "Extended Play," or "EP," record. The new records will play up to 8 minutes to a side, or a total of 16 minutes for each record. They are the same size and operate on the same turntables at the same speed as standard 45-rpm records.

Harold T. Sawyer has been appointed manager of industrial products sales in the Engineering Products Department of RCA Victor. Mr. Sawyer will be in charge of the company's varied line of industrial equipment.

Motorola Notes. Conventional home radio sets can be mass produced mechanically, including the entire circuitry, it has been announced by Motorola, Inc. Known as the "placir" plated circuit process, this development means that radios made with plated circuits will work better, sound better, last longer, need less attention, and be lighter and more compact. Plated circuits can be mass produced with uniformity, with practically no deviation in electrical or physical characteristics. In the plated circuit process, a pattern of extremely thin copper is applied to a stamped plastic base duplicating the wiring layout of the set. Each line and part of the pattern is an electric conductor replacing a wire. Sockets into which tubes and other parts are plugged are made by boring holes into the plastic base when the circuit is applied. The entire circuit is automatically fabricated by machine.

Lester C. Harder has been appointed assistant manager and John B. O'Donnell director of purchasing for the National Defense Department of Motorola, Inc. M. M. Elliott has been appointed general manager of Motorola Canada Ltd., Canadian subsidiary of the company.

Packard Promotions. Albert H. Behnke and C. Wayne Brownell have been elected vice-presidents of the Packard Motor Car Company. Mr. Behnke was formerly with the General Electric Company and Mr. Brownell was manager of industrial relations at Packard.

Fred J. Walters, vice-president and assistant to the president, has been elected vice-president of marketing; LeRoy Spencer, executive vice-president, has resigned that office and has been named West Coast manager; and Wilmer B. Hoge, assistant comptroller, has been promoted to comptroller, in other Packard organizational changes.

Eugene C. Hoelzle, vice-president, comptroller, and secretary, resigned those positions and retired September 1. He had been financial officer for Packard for 38 years.

United States Steel Appointments. H. D. Moulton, vice-president—operations, United States Steel Products Division of United States Steel Company, has been appointed assistant vice-president—raw materials, United States Steel Company. Charles L. Ficker, plant superintendent of United States Steel Products Division in Los Angeles, Calif., has been appointed vice-president—operations of the Steel Products Division. Peter C. Pianta, manager of industrial relations of the Los Angeles plant, will fill the post vacated by Mr. Ficker. G. F. Goetzinger has been appointed vice-president—treasurer of the Oil Well Supply Division of the company. William F. Jones has been appointed manager of sales, Chicago District Office, and Glendon P. Robb has been named manager of sales, New York District Office of United States Steel's National Tube Division.

National Electric Announcements. National Electric Products Corporation has announced the following personnel appointments: C. Wesley Merritt has been named sales manager of the railroad department; Robert Johnson has been appointed product engineer in charge of engineering development of Underfloor Raceway, Surface Raceway, Plug-In Strip, and Mechanical Connectors: George W. Hartner has been appointed director of advertising and publicity; and J. L. Bauer has been named assistant to the vice-president and general sales manager, all appointments effective immediately.

Alcoa Advancements. Lawrence Litchfield, Jr., has been elected president of Alcoa Mining Company, New York, N. Y., and of Surinaamsche Bauxite Maatschappij, Paramaribo, Surinam, both subsidiaries of Aluminum Company of America. He succeeds Frank B. Cuff, who retired August 1. Raymond T. Whitzel has been made general manager of the smelting division of the company, succeeding V. C. Doerschuk, who had been general manager of that division since 1935. Mr. Doerschuk will become technical consultant, chiefly on aluminum smelting and related problems. H. L. Smith, Jr., has been made staff manager—product sales for Aluminum Company of America. Mr. Smith, a veteran of 38 years service with the company, was formerly manager of sheet and plate sales. W. T. Mitman, who is now with the Washington, D. C., sales office, will succeed Mr. Smith.

(*Continued on page 24A*)

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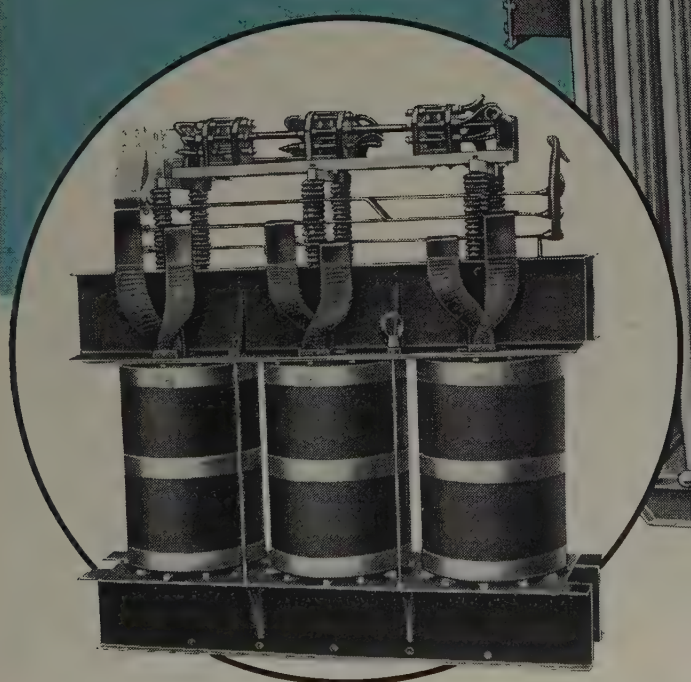
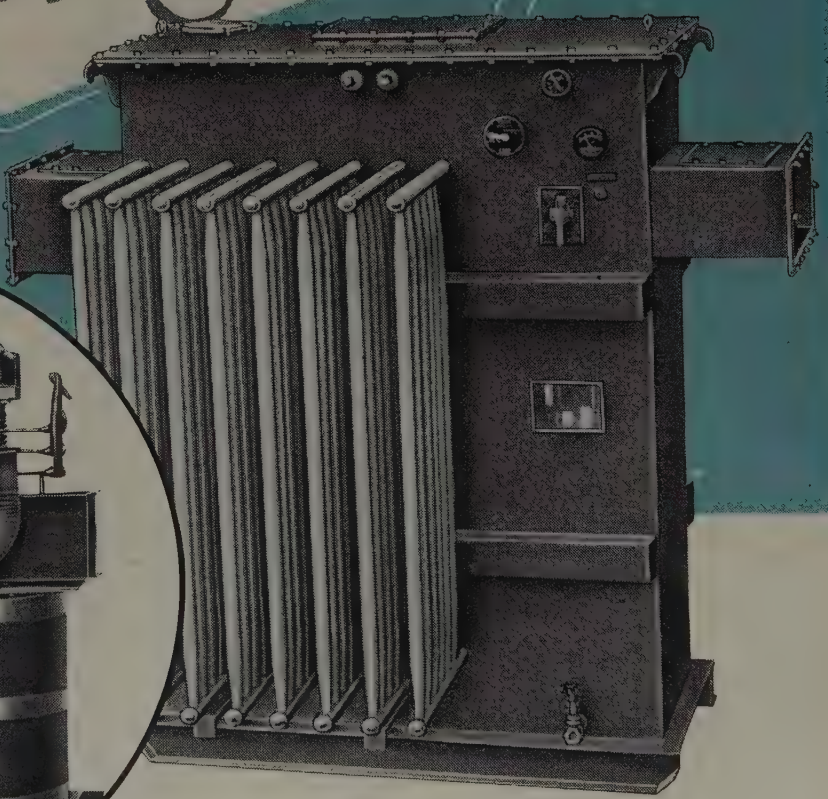
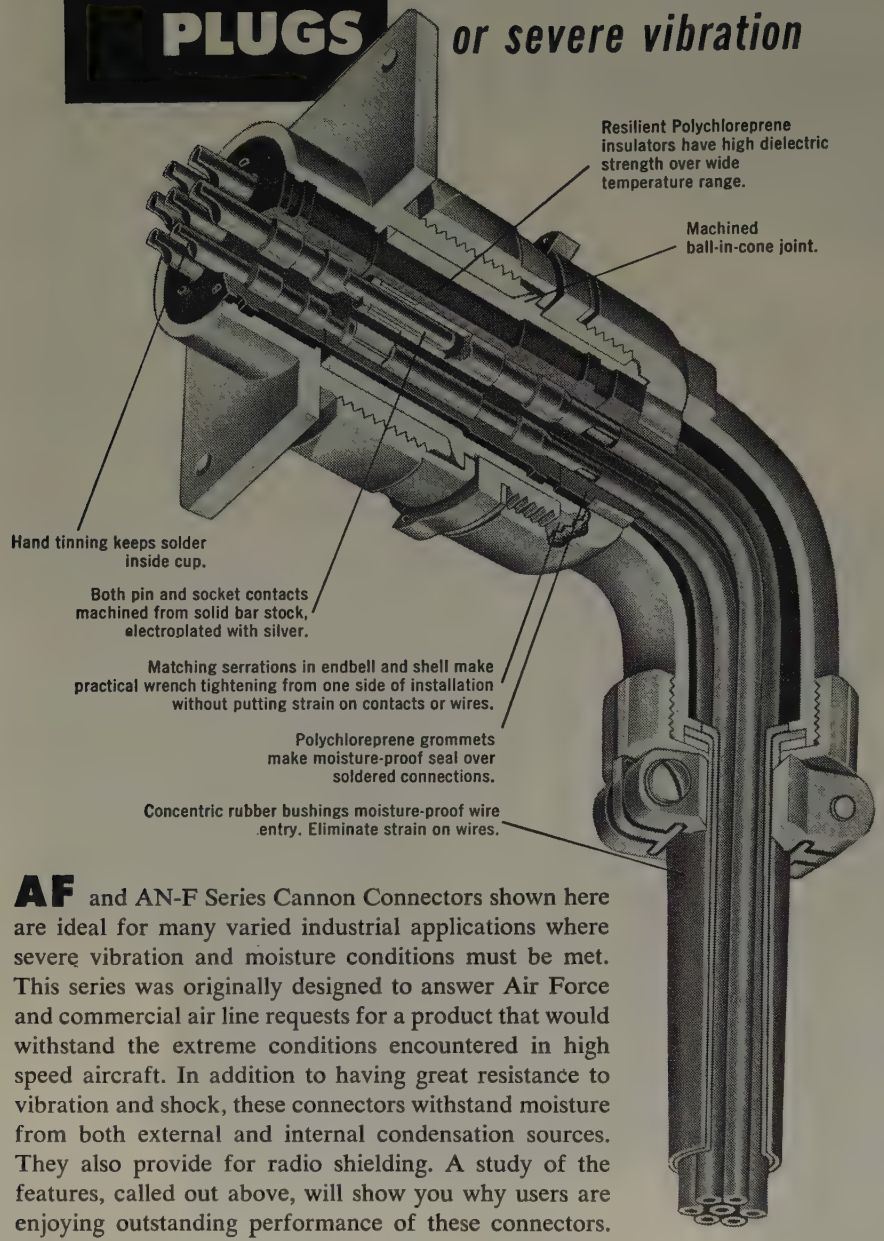




This 1500 KVA Uptegraff indoor Unit Substation Transformer is one of three identical units supplied complete—including switchgear—by Uptegraff for a large mid-western industrial firm. The sturdy design of core and coil assembly is clearly evident in the photograph at the left. The strong, rigid tank is designed to withstand eight pounds pressure or vacuum. Transformer is designed for sealed-tank operation, and a super-sensitive electronic leak-detector is used to insure that even the smallest leaks in tanks and bushings are completely eliminated. Transformer is rated at 1500 KVA, 2400-480 volts, 3 phase.

R. E. UPTEGRAFF MANUFACTURING CO. SCOTTDALE, PENNSYLVANIA

CANNON PLUGS *to withstand moisture or severe vibration*



AF and AN-F Series Cannon Connectors shown here are ideal for many varied industrial applications where severe vibration and moisture conditions must be met. This series was originally designed to answer Air Force and commercial air line requests for a product that would withstand the extreme conditions encountered in high speed aircraft. In addition to having great resistance to vibration and shock, these connectors withstand moisture from both external and internal condensation sources. They also provide for radio shielding. A study of the features, called out above, will show you why users are enjoying outstanding performance of these connectors. The machined ball-in-cone joint, while not obvious, plays an important part in providing radio shielding and improved vibration and moisture resistance. For engineering data request Cannon's AN Bulletin.

The Cannon AF Series consists of 2 plug types and 3 receptacles in 15 diameters. Contact arrangements closely follow those in the AN Series. Shells are cadmium plated. The sturdy hex shaped coupling nut shown here is used on sizes 8S through 18. Larger diameters have a strong spline type coupling nut to fit spanner wrenches. Knurled type coupling nuts are available to meet AN-F specification.

CANNON ELECTRIC

Since 1915

Factories in Los Angeles, Toronto, New Haven, Benton Harbor. Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. J-117, P.O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.

(*Continued from page 18A*)

Du Mont Promotions. R. G. Scott has been named manager, sales engineering, of the Cathode-ray Tube Division, Allen B. Du Mont Laboratories, Inc. For the past 2 years, Mr. Scott has been head of the Commercial Engineering Section of Cathode-ray Tube Sales. Edwin B. Hinck has been named replacement sales manager, following the consolidation of all Du Mont jobber sales. Mr. Hinck was formerly manager of Du Mont electronic parts sales. M. G. Scheraga has been promoted to the post of assistant technical sales manager of the company's Instrument Division.

Babcock and Wilcox Changes. David W. Jones, Jr., sales representative for the Tubular Products Division, The Babcock and Wilcox Company, has opened new offices in the Goby Building, 1321 Bannock Street, Denver, Colo. Mr. Jones handles the Division's complete line of seamless and welded, carbon, alloy, and stainless steel tubing in the Rocky Mountain area. William H. Old and E. E. Reagle have joined the company as director of purchasing and member of the technical staff of the sales department of the Tubular Products Division, respectively.

Borg-Warner News. Reflectal Corporation, the nation's largest producer of aluminum foil blanket-type insulation, has been acquired by Borg-Warner Corporation and will be operated as a subsidiary. Products will be distributed through the combined sales organizations of both Reflectal and the Ingersoll Products Division of Borg-Warner. R. S. Ingersoll, president of Ingersoll Products, also will serve as president of Reflectal. W. R. Julius, previously vice-president of Reflectal, has been named vice-president and general manager.

Offices of Norge Heat Division have been moved from Detroit to Kalamazoo, Mich., in order to co-ordinate the Norge activities with the Ingersoll organization at Kalamazoo.

E. Swain Russey has been elected president of the Warner Gear Division, succeeding A. P. Emmert. Four new vice-presidents who were appointed are T. J. Ault, W. H. Cortwright, J. C. Oesterle, and A. W. Rose.

L. G. Porter and R. P. Johnson have been elected vice-presidents of Borg-Warner International. R. A. Brown has been elected treasurer; J. W. DeLind, Jr., and R. W. Dose were re-elected president and secretary, respectively. W. B. Johnson has been appointed sales promotion manager of Norge Heat Division.

Allis-Chalmers Expansion. Allis-Chalmers Manufacturing Company has purchased the plant of Victor Electric Products, Inc., Cincinnati, Ohio. Purchase of the plant fills a need for additional space and shipping facilities for Texrope drive equipment. Within the next few months all Texrope sales, engineering, and pro-

(*Continued on page 32A*)

Oil and Air Circuit Breakers • High and Low Voltage Switchgear
Unit Substations • Instruments • Precision Balances
Watthour Meters • Disconnect Switches • Outdoor
Hook Stick Switches • Air Break Switches
Indoor and Outdoor Bus Supports
Bus Ducts • Substations

ROLLER SMITH

ROLLER-SMITH CORPORATION AND ELPECO DIVISION

BETHLEHEM, PENNSYLVANIA

ELPECO

THE Standard TRADE MARK ®

TRANSFORMER COMPANY
AT YOUR SERVICE

Save time on your engineering projects by using the services of STANDARD'S experienced engineers to detail transformer requirements. Call your nearest STANDARD representative for information on this useful service.

DESIGNING

Specifying transformers for electric systems or equipment is a routine of STANDARD'S staff. Design engineering of special transformers for specific functions is a service our men are particularly qualified to render. Years of this specialized experience will save time and eliminate experimentation.

MANUFACTURING

Manufacturing of STANDARD'S transformers is conducted under the eyes of the designing engineers. A more than usual amount of handwork is practiced in the STANDARD factory to assure better quality. Only craftsmen of rated experience are assigned to critical tasks.

TYPES OF TRANSFORMERS

POWER • DISTRIBUTION • INSTRUMENT
STREET LIGHTING • TESTING
OIL, ASKAREL OR AIR COOLED

THE STANDARD TRANSFORMER CO.
WARREN · OHIO
(EXCLUSIVELY TRANSFORMER DESIGNERS AND MANUFACTURERS)

(*Continued from page 24A*)

duction facilities will be moved into the new plant from West Allis, Wis. With this move, office and production facilities of all the Allis-Chalmers Apparatus Division will be consolidated in two plants under J. D. Greensward, general manager, Norwood (Ohio) Works. This includes small and medium size motors and pumps, and Texrope drives and transmission equipment.

R. S. Stevenson has been elected executive vice-president of the company. He was formerly vice-president in charge of the tractor division. Willis G. Scholl, formerly vice-president and general sales manager of the tractor division, was named to succeed Mr. Stevenson. Named to succeed Mr. Scholl was Frank Mussell, eastern territory manager of the tractor division.

Sylvania Appointments. Dr. Ben Kievit has been named manager of sales engineering for the Radio and Television Picture Tube Divisions of Sylvania Electric Products, Inc. H. S. Moncton has been appointed administrative engineer of the Radio and Television Division. Irwin Goldman will succeed Mr. Moncton as assistant to the manager of the Physics Laboratories. Robert Adelson has been named to the legal staff. He will be staff attorney to the corporation's controller, treasurer, and secretary, devoting a substantial part of his time to legal problems in the tax field.

NEW PRODUCTS • •

High-Bay Reflector Lamp. A new high-bay reflector lamp designated the *R-52* has been announced by Sylvania Electric Products Inc., Salem, Mass. The *R-52* is available at ratings of 500 or 750 watts, and has a rated average life of 2,000 hours. It has a mogul base and was designed for a base-up burning position, or within 25 degrees of vertically base up. The new units have a *C-7A* filament construction with a collector grid and have a maximum over-all length of $11^{3}/_{4}$ inches. They operate at 115, 120, and 125 volts. Designed for high-bay lighting in factories, the lamps require no special fixture except where needed for protection.

RCA Tubes. The Radio Corporation of America has announced the development of the following new tubes. *RCA-12AX4-GT* is a half-wave vacuum rectifier of the heater-cathode type designed primarily for use as a damper tube in horizontal deflection circuits of television receivers utilizing series-heater strings. Designed with insulation between heater and cathode to withstand negative peak pulses between heater and cathode of as much as 4,000 volts with a d-c component up to 900 volts, the *12AX4-GT* provides flexibility in choice of deflection circuits.

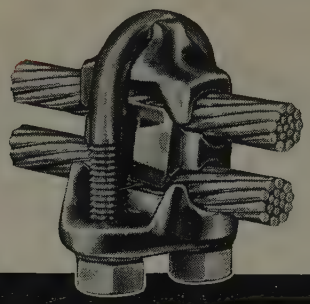
RCA-6CL6 is a power pentode of the

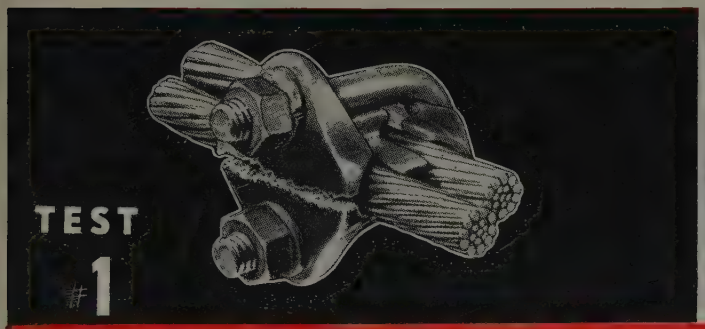
(*Continued on page 38A*)

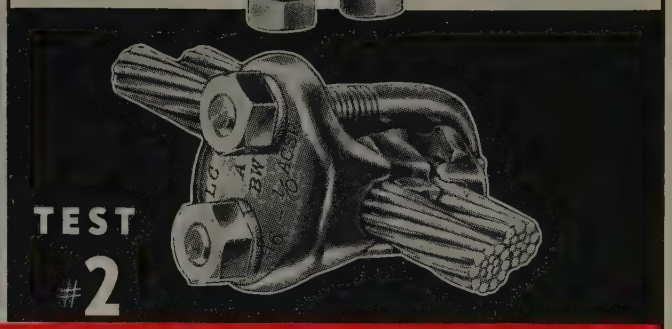
Semblance of Design DOES NOT Prove Equal Quality!

For Continuity of Service *Be Sure by Test* Aluminum Clamping Members Have Greater Strength than Hardware Components

Aluminum Distribution Connector Assembled with Maximum Size Cables in Both Grooves.







TEST STANDARD: 500 Inch Pounds Minimum Torque for ⅜ inch Diameter "U" Bolts.

TEST #1 Conducted on CONNECTORS of OTHER MANUFACTURE

Torque: *Below* minimum test standard applied in several tests caused deformation or fracture of clamping members and failure of ⅜ in. "U" Bolts.

TEST #2 Conducted on ABW CONNECTORS

Torque: *Above* minimum test standard applied in all tests caused no failures of ⅜ in. "U" Bolts and no deformation or fracture of clamping members.

EXAMINATION OF CONNECTOR COMPONENTS THAT FAILED IN TEST NO. 1 REVEALED:

- IMPROPER OR NO HEAT TREATMENT OF CASTINGS
- POROSITY AND IMPURITIES IN METAL
- COLD RUN OF METAL DURING CASTING PROCESS
- IMPROPER ALLOY USED

Be Sure Buy Aluminum Connectors, Clamps, Fittings and Accessories backed by more than *25 Years* of Electrical, Mechanical and Metallurgical Knowledge and Manufacturing Experience gained in Meeting and Maintaining the most Exacting Standards of the Electrical Industry.

OUR PRODUCTS ARE QUALITY CONTROLLED FROM INGOT TO FINISHED PRODUCT

CONSULT ONE OF OUR NEAREST EIGHTEEN REPRESENTATIVES OR CONTACT OUR MAIN OFFICE

ANDERSON BRASS WORKS, INC.

Aluminum *Bronze*

POST OFFICE DRAWER 2151

BIRMINGHAM, 1, ALABAMA

SUBSTATION — TRANSMISSION — DISTRIBUTION

Power Connectors, Clamps, Fittings and Accessories

POWER RELAYS
SMALL RELAYS
SENSITIVE RELAYS
LATCH RELAYS
INSTRUMENT-CONTROLLED
RELAYS and SETS
SEQUENCE RELAYS
TIMING UNITS
SPECIAL-PURPOSE RELAYS

5,348
RELAY TYPES

...mean that you get exactly the right relay for the job!

STRUTHERS
-DUNN

Struthers-Dunn, Inc., 150 N. 13th St., Philadelphia 7, Pa.

BALTIMORE • BOSTON • BUFFALO • CHARLOTTE • CHICAGO • CINCINNATI
CLEVELAND • DALLAS • DETROIT • KANSAS CITY • LOS ANGELES
MINNEAPOLIS • MONTREAL • NEW ORLEANS • NEW YORK • PITTSBURGH
ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

(*Continued from page 32A*)

9-pin miniature type designed specially for use in the final video stage of television receivers. It is also useful as a wide-band amplifier tube in industrial and laboratory equipment. Features of the *6CL6* include very high transconductance, 11,000 micromhos, low capacitances, and high output-current capability. Because of these features, it is possible to obtain a voltage gain of from 40 to 45 in wide-band video circuits. Providing high plate current at low plate voltages, the *6CL6* can supply sufficient peak-to-peak output voltage to drive large picture tubes with high efficiency and low amplitude distortion. Separate base-pin connections for grid number 3 and cathode permit the use of an unby-passed cathode resistor to provide degeneration without encountering parasitic oscillations which would result if the suppressor were internally connected to the cathode.

RCA-3C45 is a hot-cathode 3-electrode hydrogen thyratron designed for pulsing service involving high repetition rates, high peak currents, and low average currents in low-impedance circuits. It is specially useful for pulsing magnetron oscillators and other oscillators having a power input up to 50 kw. Features of the *3C45* include its very short deionization time, low voltage drop, high peak anode current capability, ambient-temperature operating range of −50 degrees to +90 degrees centigrade, and positive-control characteristic which permits zero-bias operation utilizing positive triggering pulses.

Small Precision Servo Motor. G-M Laboratories, Inc., Chicago, Ill., has introduced a small servo precision motor 1.7 inches in diameter and $1\frac{3}{4}$ inches long, for frequencies varying from 60 to 400 cycles, and in 2-, 4-, or 8-pole construction. One motor has been supplied for 800-cycle use. Stall torque is approximately 2 inch-ounces, and in some instances well above that figure. Housings are stainless steel or aluminum. Output shaft can be supplied to suit, with or without integral pinion. These motors can be supplied to meet rigid military specifications with regard to humidity, temperature, range, vibration, and altitude. Further information may be obtained by writing the manufacturer, G-M Laboratories, Inc., 4300 North Knox Avenue, Chicago, Ill.

Air-Cooled Flame Rectifier Head. An air-cooled flame rectifier head for use on applications where temperatures around furnace walls are more than 1,300 degrees Fahrenheit has been developed by the Industrial Division of Minneapolis-Honeywell Regulator Company. A companion device, a chuck adapter, has been designed for changing any Honeywell insulator-type flame head to a right-angle electrode holder. The rectifier head is also for use when a positive pressure inside a burner tends to force out heat around head and chuck. The basic unit consists of the

(*Continued on page 52A*)

MAGNET WIRE

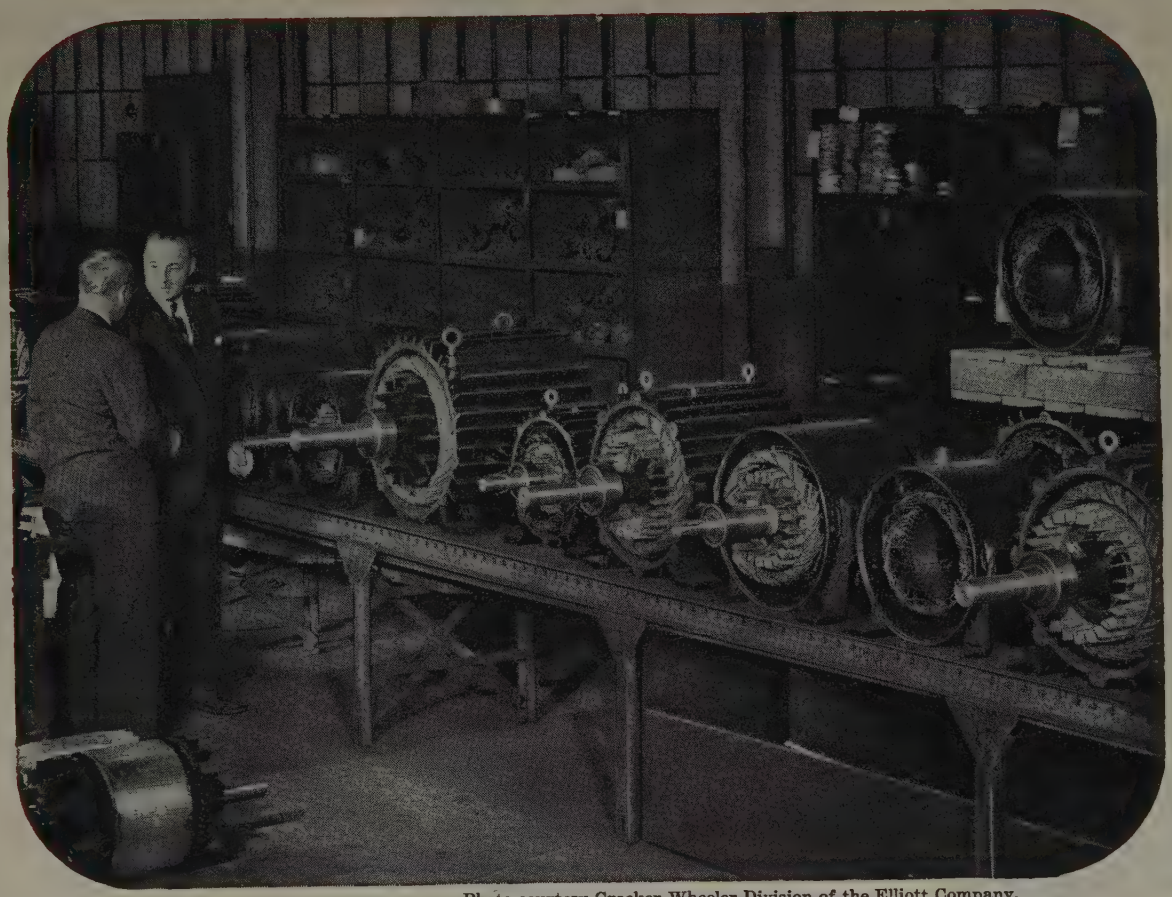


Photo courtesy Crocker-Wheeler Division of the Elliott Company.

Roevar . . . you can't buy a finer magnet wire

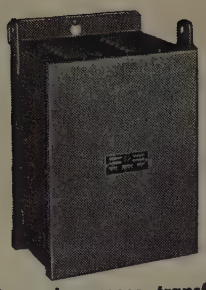
CONTINUAL IMPROVEMENT is a distinguishing feature of Roebling's electrical wire and cable line. And to make Roebling Roevar Magnet Wire today's A-1 specification for high speed winding, we use the toughest insulation we know of.

This Roevar insulation is *many times* more abrasion-resistant than conventional enamels. It is highly resilient . . . bends to a remarkable degree without cracking or coming loose from the conductor. On top of that, it has extra resistance to the solvents that are used in coil-treating varnishes and to all usual baking temperatures.

Roevar Magnet Wire comes in sizes No. 14 to 40 A.W.G. . . . and its small diameter is an important factor in many applications. You can depend on us for the best deliveries possible under today's conditions. John A. Roebling's Sons Company, Trenton 2, N. J.

ROEBLING

ATLANTA, 934 AVON AVE • BOSTON, 51 SLEEPER ST & 5 PITTSBURGH ST • CHICAGO, 5525 W. ROOSEVELT RD • CINCINNATI, 3253 FREDONIA AVE • CLEVELAND, 13225 LAKEWOOD HEIGHTS BLVD. • DENVER, 4801 JACKSON ST • DETROIT, 915 FISHER BLDG • HOUSTON, 6216 NAVIGATION BLVD • LOS ANGELES, 5340 E. HARBOR ST & 120 S. HEWITT ST • NEW YORK, 19 RECTOR ST • ODESSA, TEXAS, 1920 E. 2ND ST • PHILADELPHIA, 230 VINE ST • PITTSBURGH 1301 CLARK BLDG • ROCHESTER, 1 FLINT ST • SAN FRANCISCO, 1740 17TH ST • SEATTLE, 900 1ST AVE S. • ST. LOUIS, 3001 DELMAR BLVD • TULSA, 321 N. CHEYENNE ST • EXPORT SALES OFFICE, TRENTON 2, NEW JERSEY

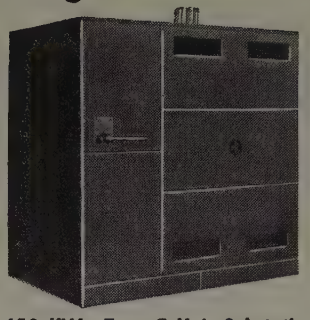


TYPE C

General purpose transformers, 600 volts and below; 1-15 KVA inclusive, single or three phase

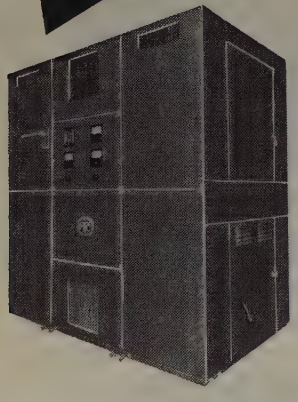
HIGH efficiency

MARCUS DRY TYPE transformers



450 KVA, Type F Unit Substation, 4160 V. Delta, 60 Cycles, 3 Ø—120/208Y, 4 wire.

LOW maintenance



1500 KVA, Type F Unit Substation, 4800 V Delta 60 Cy, 3 Ø—120/208Y, 4 wire.

Years of specialization in the dry type transformer field have resulted in a far superior product. Being ahead of the rest of the field is the natural result of continuous effort and research in uncovering new materials which are your constant assurance of maximum transformer value.

MARCUS DRY TYPE, AIR-COOLED TRANSFORMERS

ARE SAFE — No explosion or fire hazards. No fire proof vaults. Class B and C heat proof insulations.

ARE ECONOMICAL — Lower cost installation and operation, negligible maintenance.

For the transformer that's second to none, specify MARCUS.

ONE OF THE WORLD'S LARGEST MANUFACTURERS OF DRY TYPE TRANSFORMERS EXCLUSIVELY

1 to 2,000 KVA up to 15,000 Volts to meet Individual Requirements

- DISTRIBUTION
- GENERAL PURPOSE
- UNIT SUBSTATION
- PHASE CHANGING
- ELECTRIC FURNACE
- RECTIFIER
- WELDING
- MOTOR STARTING
- SPECIAL

NEMA

Representatives in Principal Cities

MARCUS TRANSFORMERS CONFORM TO THE STANDARDS OF N.E.M.A. AND A.I.E.E.

MTC

MARCUS TRANSFORMER CO. INC.

32 MONTGOMERY STREET

HILLSIDE 5, NEW JERSEY

PIONEERS IN THE FIELD OF AIR-COOLED TRANSFORMERS

(*Continued from page 38A*)

head, an airtight electric connector, an 8-inch stainless steel rod and chuck assembly, and an outside pipe support and insulator. When in use, the new chuck adapter is connected to the flame head at one end, and the opposite end is drilled for a 3/16-inch diameter rod that will run at right angles. The arrangement permits the electrode to be mounted at various distances from the flame head, resulting in greater accessibility to a flame by the electrode, but without damage to the head.

Deadend Clamp. To simplify the deadending of large diameter aluminum conductors in primary and secondary distribution, and in station busses, the Ohio Brass Company, Mansfield, Ohio, has announced a line of five Strateline deadending clamps that will accommodate cables from 0.15 to 1.55 inches in diameter. The four smaller sizes are intended for use on distribution lines where tensions seldom exceed 2,000 pounds per phase, and where surplus clamp strength is considered less desirable than small bulk, greater convenience in handling, and lower cost. The largest clamp, having a slip strength of 8,000 pounds, has been designed principally for station bus support. Available in malleable iron, bronze, or aluminum, with liners for malleable iron clamps available on request, it is possible to match clamp and conductor metals in order to minimize electrolytic attack. These clamps all have slip strength safety factors of three or more on low-tension applications and are easy to work by hot sticks or by hand.

Digital Computer Tube. A new tube designed and tested specifically for use in high-speed digital computers has been announced by the General Electric Tube Department. The tube, type number *GL-5965*, is a miniature twin triode for use in several of the different circuits used in digital computers. It incorporates a special heater-cathode construction designed for dependability under frequent "on-off" switching conditions. When used in on-off control applications, the *GL-5965* will maintain its emission capabilities after long periods of operation under cutoff conditions. Each triode section features a high zero-bias plate current, a sharp cutoff characteristic, and a separate cathode connection. In addition, the balance of the cutoff characteristic between the two sections is controlled. Average characteristics of the *GL-5965* with 150 volts on the plate are cathode bias resistor, 220 ohms; amplification factor, 47; approximate plate resistance, 7,250 ohms; transconductance, 6,500 microhms; plate current, 8.2 milliamperes. Typical operating characteristics for each section in computer service: "On" condition—plate supply voltage, 150 volts; plate load resistor, 7,200 ohms; grid voltage, 0; approximate plate current, 10.5 milliamperes. "Off" condition—plate supply voltage, 150 volts; plate load resistor, 7,200 ohms; approxi-

(*Continued on page 56A*)

INTERNATIONAL RECTIFIER CORPORATION

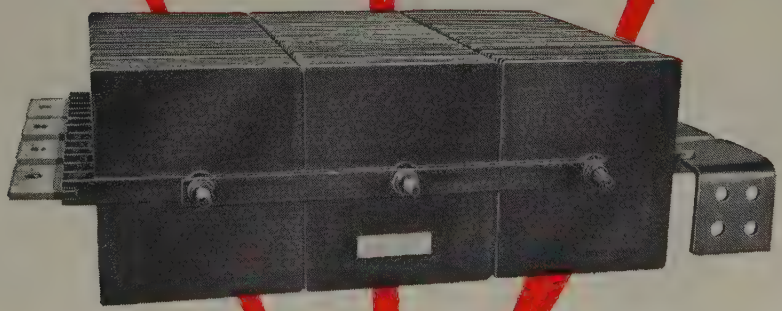
EL SEGUNDO
CALIFORNIA

HERMETICALLY SEALED
Diameter.....3/16" to 1-1/4"
Length.....9/16" to 10"
Current: half-wave..1.5 ma to 60 ma
Voltage: DC output.....20 volts to 4,000 volts

PHENOLIC CARTRIDGE
Diameter.....⅛" to 1"
Length.....½" to 12"
Current: half-wave..1.5 ma to 60 ma
Voltage: DC output....20 volts to 10,000 volts

SELENIUM DIODES
Diameter.....0.100" to 0.300"
Length.....0.210" to 0.250"
Output Voltage.....20V to 80V
Output Current...2[illegible]0 ua to 1.5 ma
Temperature Range -50°C to 100°C

Selenium Rectifiers



A recent month's production included Rectifiers to supply 40 microamperes, 1,000 volts, and Rectifiers with a capacity of 140,000 amperes, 14 volts.

POWER STACK
30 Kw DC Power
Considered to be the largest single selenium rectifier stack produced.

Owned and managed by Engineers who are specialists in the design and manufacture of Selenium Rectifiers. Submit your problems for analysis and we will be glad to offer our recommendations.

C O R P O R A T I O N

General Offices: 1521 E. Grand Ave., El Segundo, Calif. - Phone: El Segundo 1890
Chicago Branch Office: 205 West Wacker Drive - Phone: Franklin 2-3889

Before you buy anybody's MICROWAVE SYSTEM

Consider these 5 facts!

1. Who is the manufacturer?

When you specify RCA, the answer is easy. Because RCA is the world's greatest name in radio, television, and related activities. RCA has pioneered in high-frequency radio communications and really knows microwave from start to finish.

2. What has he actually done in the microwave field?

Again, RCA has rolled up an impressive record. Installed and operating are more than 19,000 channel miles of RCA microwave systems, for pipelines, power utilities, turnpikes, and government agencies. One system is over 1000 miles long, extends from New York to Washington and Pittsburgh. And after three years' continuous experience, expansion is being planned . . . proof enough of *outstanding RCA performance.*

3. Is he equipped to install microwave?

Again, with RCA, the answer is "yes." RCA will handle your installation for you . . . will even furnish you with a detailed aerial survey of the microwave route.

4. Is he equipped to maintain microwave?

Again, RCA is out in front, with a nationwide service organization geared to handle your microwave maintenance on a 24-hour basis. It's the *RCA Service Company*—already well known for its service to industry on other types of electronic equipment. It's available to you when *you* specify RCA.

5. Is the equipment designed with an eye to the future?

Yes . . . if it's RCA equipment.

For instance—consider the matter of adding additional voice and signal channels. Thanks to RCA's "eye to the future" design, you can add or drop channels at any station with a minimum of cost . . . a minimum of equipment.

Why settle for less than RCA MICROWAVE?

When you start talking about microwave, you're talking about *money.* So isn't it just good sense to be sure you invest in the best? With RCA, you're dealing with the leading name in radio . . . with men who *know* microwave. *So specify RCA—and be sure.*

You get these 7 plus features with RCA Microwave

1. Uses conventional tubes throughout.
2. Easy to tune. Has built-in metering.
3. Handles large number of single sideband frequency division channels without excessive cross-talk.
4. Flexible. Any or all voice or control channels can be picked up or dropped at any station, repeater or terminal.
5. Service channel with signaling available at each repeater and terminal station.
6. Vertical space, provides ready access both front and rear.
7. Designed, built, and backed up, by RCA . . . world leader in electronics.

RCA

RADIO CORPORATION of AMERICA

MORE INFORMATION? MAIL COUPON TODAY

RCA Communications, Dept. 42J, Camden, N. J.

Without obligation, please send me more information on RCA Microwave for the specific application indicated:_____

Name_____

Position_____

Company_____

Address_____

City_____ State_____

☐ Please have an RCA Microwave Engineer call on me.

(*Continued from page 52A*)

mate grid voltage for plate current of 150 microamperes, −5.5 volts.

Ceramic Capacitors. Molded in moisture-resistant thermosetting plastic, rated at 20,000 volts direct current, and designed for 85 degrees centigrade operation, type *700C* high-voltage ceramic capacitors have been introduced by the Sprague Electric Company, 32 Marshall Street, North Adams, Mass., for use as high-voltage supply filters in television receivers and cathode-ray instruments. Standard rated capacitance is 500 magnetomotive forces. Terminal combinations are available to meet any mounting requirement. The capacitors withstand a dielectric test potential of 30,000 volts. Minimum insulation resistance under standard test procedures at 25 degrees centigrade is 10,000 megohms. Sprague Bulletin *606* giving complete details is available on letterhead request to the manufacturer.

Electrical Computer. The model *30-103* Electrical Computer, designed for rapid solution of as many as 12 simultaneous linear equations, has been announced by Consolidated Engineering Corporation, Pasadena, Calif. The computer, applicable to many fields such as electric circuit study, aircraft flutter analysis, and statistics, is fast and accurate. The power supply operates on 115 volts, 60 cycles, alternating current. The computer is described in bulletin *CEC-1802A* available from the company.

Resonant Amplifier. A new type of resonant amplifier giving high Q performance at very low frequencies as well as at audio frequencies is announced by Kalbfell Laboratories, Inc., San Diego, Calif. The well-known method of incorporating a Twin-T filter in the feedback loop of an amplifier is employed, but some novel direct coupled features give stable values of Q up to 100 plus feedback stabilization of gain even at the peak of the frequency response curve. Further details are available from Kalbfell Laboratories, Inc., P. O. Box 1578, San Diego, Calif.

Diode Tester. An instrument for testing the dynamic as well as static characteristics of crystal diodes has been developed by Computer Research Corporation, Hawthorne, Calif. The new *CRC* diode tester tests both forward and back characteristics under static and dynamic conditions, telling how the diode will perform before mounted in the circuit. Where large numbers of diodes are used in plug-in form, the diode tester can be used for periodic circuits checks to detect potential diode failures before they occur. It occupies a space less than 1/2 cubic foot and will accommodate diodes with forward currents of 0 to 100 milliamperes and back currents of 0 to 1,000 microamperes. Forward voltage is measured to an ac-

(*Continued on page 64A*)

Sub-Stations and Power Centers

for indoor installations

Engineered to meet your exact requirements

Not necessary to design or change your installation to fit a "standard"

Any type of primary switch gear.
Metering—primary or secondary, to suit.
Secondary breakers, main, branch, or tie.

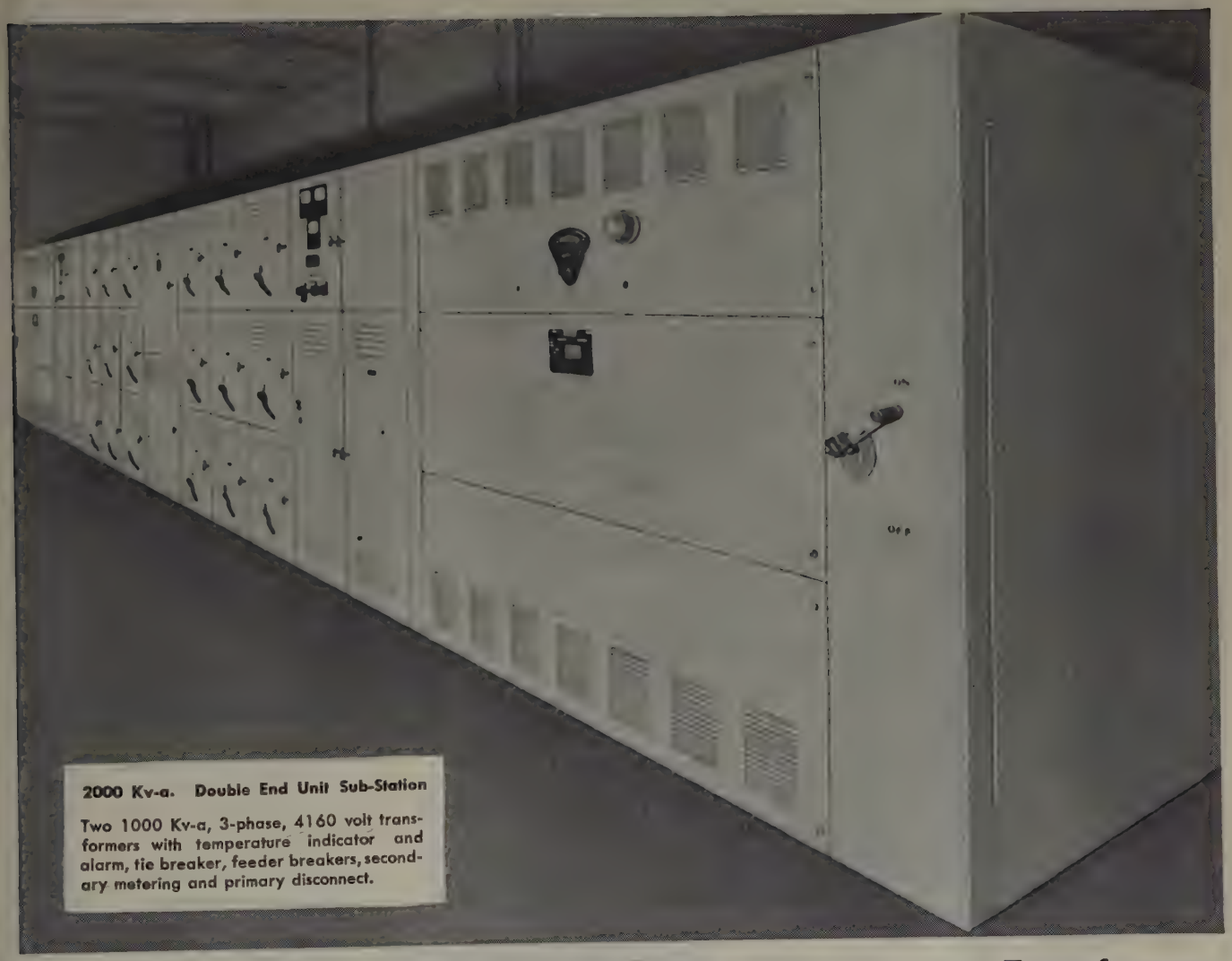
Interlocked or automatic throw-over. Draw-out or stationary types. Magnetic trip, or thermal.

All incorporated with high quality, liberally designed **SORGEL Air-Cooled Transformers.**

All factory assembled, wired and tested. **Mounted on a substantial steel base.**

Shipped as a single unit or in sections, accurately co-ordinated for **easy assembly on the job.**

Sizes up to 2000 Kv-a. **All voltages up to 15 KV.**



2000 Kv-a. Double End Unit Sub-Station

Two 1000 Kv-a, 3-phase, 4160 volt transformers with temperature indicator and alarm, tie breaker, feeder breakers, secondary metering and primary disconnect.

Also a Complete Line of Conventional Air-Cooled Dry-Type Transformers

¼ to 2000 Kv-a. Single phase and poly-phase. 120—240—480—600 volts.

Sales Engineers in Principal Cities

SORGEL ELECTRIC CO. 846 West National Ave., Milwaukee 4, Wis.

Pioneers in the development and manufacturing of Air-Cooled transformers

Rate Measuring
GYROSCOPES
for

Control
Stabilization
Flight Testing
Rate Computation

For the accurate measurement of absolute rates of angular rotation, the Doelcam Model K Rate Measuring Gyroscope offers the following features:

1. Accuracy: 0.5%
2. Resolution: 0.1%
3. Maximum uncertainty: 0.2%
4. Hermetically sealed
5. Shock and vibration resistant
6. Microsyn pickoff: 60 — 5,000 cps
7. Thermostatically controlled damping ratio
8. Small size: 3 inches diameter x 5.82 inches
9. Lightweight: 3 5/8 lbs.

The design of the Model K Gyroscope affords wide latitude in the adjustment of parameters and permits design to any particular specifications.

For complete details write for Bulletin K

DOELCAM CORPORATION 56 Elmwood Street Newton 58, Massachusetts

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Specify **PINCO**

and PINCO PERFORMANCE will prove the wisdom of your choice!

Whatever your requirements may be—whether for electrical porcelain of either standard or special design, it will pay you to put your problems up to Pinco! In doing so, you will be placing responsibility in the capable hands of an organization backed by more than thirty years of experience in designing and producing the finest high-dielectric porcelain—made by the famous Pinco "wet plastic" process.

And remember too that the Pinco slogan "RIGHT ON THE JOB" is doubly significant. It expresses our ability to render efficient service –and is your guarantee of trouble-free "on-the-job" performance.

The **Porcelain Insulator Corporation**
LIMA, NEW YORK

Sales Agents:
JOSLYN MFG. & SUPPLY CO.
Offices in Principal Cities

PINCO INSULATORS

(*Continued from page 56A*)

curacy of 2 per cent and back current to 3 per cent. The tester is adaptable to high-speed volume testing and operates on 115-volt 60-cycle current, using 100 watts or less. For further information, write to the Director of Applications, Computer Research Corporation, 3348 West El Segundo Boulevard, Hawthorne, Calif.

Profiled Gear Grinder Wheels. The Jerpbak-Bayless Company, Solon, Ohio, has developed a line of Worm Face Profiled Gear Grinder Wheels in popular-make gradings and pitches. These profiled wheels are accurately formed, with proper root clearances, minimizing root crushing. The wheels require a minimum of dressing. The grinding wheel is remounted readily on a machine because the worm form profile is held square and parallel with the bore and face. Each grinding wheel is marked with the proper pitch and form for easy identification. These wheels are available through the Jerpbak-Bayless distributor, The Crown Tool and Supply Company, 155 Bell Street, Chagrin Falls, Ohio.

Ultrasonic Micrometer. Branson Instruments, Inc., Stamford, Conn., has developed an ultrasonic micrometer for use in making ultrasonic thickness measurements. Measurements within 1/2 of 1 per cent of actual thickness have been obtained from one side of materials with smooth surfaces. The micrometer can be used on homogeneous materials such as steel, brass, aluminum, copper, glass, lucite, and other dense substances capable of transmitting the ultrasonic waves generated by vibrating crystal. It is designed to operate with high precision over an infinite series of relatively narrow thickness ranges between 0.010 inch and 12 inches. Plug-in frequency coils and matched dials for any desired frequency permit the selection of the one specific frequency best suited to the required thickness range. Since the instrument accommodates two coils at once and each dial has provision for two scales, the user has two thickness ranges at his command at all times. Scales can be computed either for direct reading or to show deviations from any standard thickness desired. Full information can be obtained from Branson Instruments, Inc., 430 Fairfield Avenue, Stamford, Conn.

Low-Frequency Oscillator. A low-frequency oscillator, designed as a source of signal power in the range of 0.01 to 100 cycles per second, has been announced by the Southwestern Industrial Electronics Company, Houston, Tex. The model "*L*" oscillator features the use of resistors and capacitors for frequency determination and offers excellent short- and long-time frequency stability. The circuit has been treated as a d-c amplifier, and both plate and filament supplies have been regulated carefully. The output circuit is coupled

(*Continued on page 66A*)

HiVolt Power Supplies*

where size and weight must be kept to a minimum

These hermetically-sealed, self-contained power supplies are designed to transform AC to high voltage—low current DC for many applications. Our exclusive engineering techniques and oil-filled construction assure smaller, lighter, more flexible units.

Applications:

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- **dust and electrostatic precipitators**
- **oscilloscopes**
- **display tubes**
- **etc.**

Send us your requirements and we will recommend the best HiVolt Power Supply.

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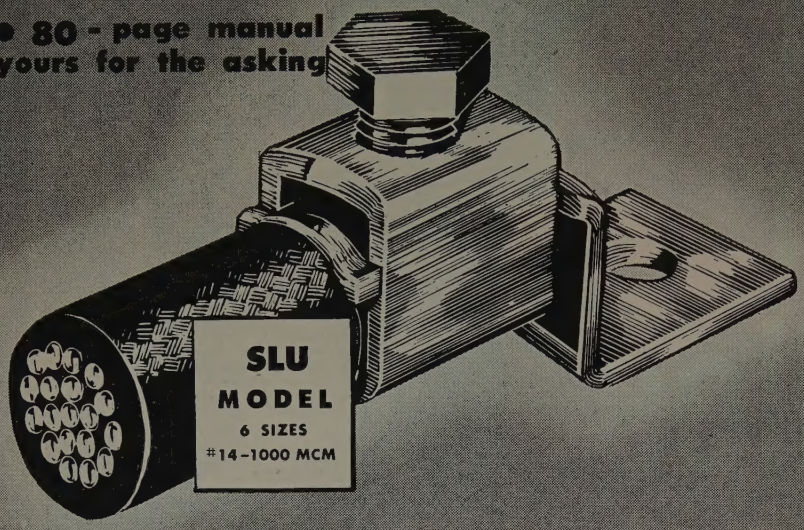

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Test analyzer for use in development and PRODUCTION of SERVOMECHANISMS and PROCESS CONTROLS. Measures FREQUENCY RESPONSE, PHASE SHIFT 0.1 to 20 CYCLES SINE WAVE, SQUARE WAVE, MODULATED CARRIER, 50 to 800 CYCLES.

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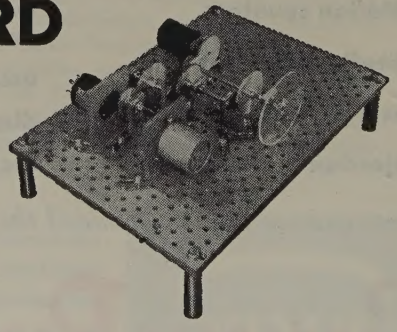
A FLEXIBLE SET of PRECISION mechanical parts for quickly coupling motors, synchros, potentiometers to form assemblies of Servo systems, regulators, computors.



SERVO CORPORATION OF AMERICA

DEPT. EE-10 NEW HYDE PARK, N.Y.

(*Continued from page 64A*)

directly to the load and will produce 20 volts or 20 milliamperes into any load impedance. This instrument is a true sine-wave generator, and the waveshape contains only low-order harmonic distortion. Two separate means for amplitude control have been provided. An oven-controlled thermistor is used as a quasilinear element where extremely low distortion is required. A varistor is provided also in a circuit which allows it to control the amplitude by creating 1 per cent or less distortion. The unit is housed in a welded aluminum cabinet 18 by 18 by 12 inches, and weighs approximately 65 pounds.

TRADE LITERATURE

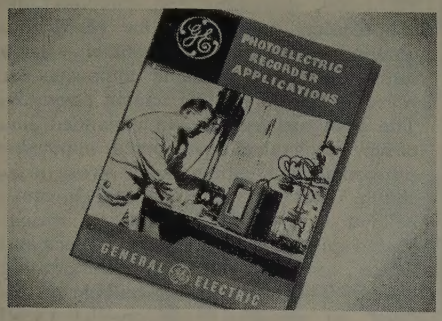
D-C Arc Welder. Up-to-date information on engineering improvements and application refinements of the type *RA* d-c arc welder are offered in a new 12-page booklet available from the Westinghouse Electric Corporation. Included is information on the performance characteristics of this welder, its physical construction, electrical specifications and ratings, and approximate dimensions and weights. Illustrated sections about dual units, Heliarc torch welding, duplex welders, stud welding, and control attachments, both arc-drive and remote, are covered. For a copy of this booklet, *B-5453*, write Westinghouse Electric Corporation, Box 2099, Pittsburgh, Pa.

Pliers and Adjustable Wrenches. Utica Drop Forge and Tool Corporation has prepared a comparative chart of pliers and adjustable wrenches. It is a carefully compiled table which cross-refers and compares the numbers of 31 manufacturers of pliers and wrenches. Some 144 pliers and adjustable wrenches are listed. Shown opposite it, for quick reference, are the brand names and tool numbers of other suppliers of similar items. Also included is a pictorial diagram showing the logical groupings of pliers by design characteristics. The 8-page folder is available on letterhead request to Educational Department, Utica Drop Forge and Tool Corporation, Utica, N. Y.

Silastic Facts. A comprehensive review of the properties and performance of Dow Corning silicone rubber is given in Silastic Facts Number 10a, recently released by the Dow Corning Corporation. The new edition, a revision of Silastic Facts Number 10, provides a detailed discussion of the characteristics of these semiorganic elastomers, devoting separate sections to their resistance to high and low temperatures, to weathering, chemicals, and hot oils, to compression set and thermal aging, and to their dielectric properties. A chart summarizes the physical characteristics of 22 leading stocks. Typical applications, including gaskets, seals, me-

(*Continued on page 68A*)

GE INSTRUMENTS FOR LABORATORIES



New Application Book Describes Use of Photoelectric Recorder

General Electric's new bulletin, "12 Applications of the Type CE Photoelectric Recorder," is just off the press. This publication describes new and unusual applications for which this versatile recorder has been found ideally suited. These stories, in addition to pointing out how industry is benefiting from the many unique qualities of the photoelectric recorder, will also suggest how the instrument can be utilized to solve other new measuring and recording problems.

HIGH-SPEED RESPONSE

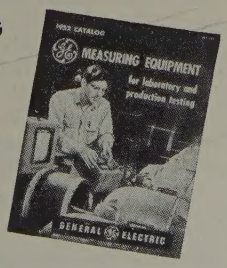
The CE recorder is designed for recording rapidly changing phenomena with a minimum burden on the measured circuit and is available with a sensitivity as low as 1 microampere full scale. Response periods can be as fast as 1/5 second for full-scale deflection. Chart speeds range from ½-inch per hour to 72 inches per minute. Prices start at $698.88* for complete equipment. Check coupon below for your copy of new bulletin GEA-5536, which describes uses of photoelectric recorder.

*Mfgs. suggested retail price.

1952 CATALOG

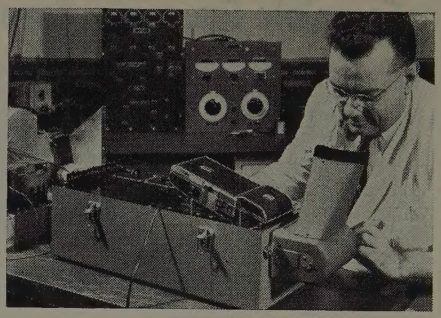
G-E Measuring Equipment

80 pages describing all of General Electric's testing and measuring devices. For free copy check GEC-1016 in coupon at right.



Three New Accessories Announced for G-E Low Cost Portable Oscillograph

Just announced are three new accessories for the G-E Type PM-18 portable oscillograph. The PM-18 is designed for industrials and schools who require a low-cost instrument which will record two, three, or four rapidly or slowly changing currents and voltages simultaneously.

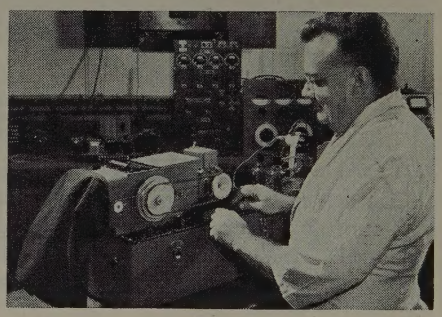


CONTINUOUS-DRIVE FILM HOLDER

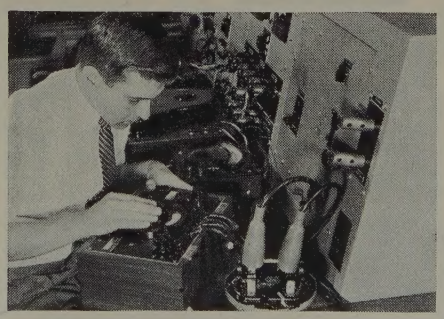
The new accessories include a continuous-drive film holder for those applications which require an extra long record; a viewing attachment for observing the wave form before taking a record; and a new high-sensitivity galvanometer with a rating of 1.67 millimeters per microampere at one meter.

A new sweep mirror is also incorporated which provides adjustable time sweep of 0.1 to 0.5 second in addition to the original non-adjustable 1/60-second sweep.

The PM-18 with Polaroid-Land film holder and 2 galvanometers cost only $773.76*. Check coupon for bulletin.



Eastern Lab Saves Time In Making Resistance Measurements With G-E Portable Double Bridge



A large eastern laboratory reports that they are able to save time and obtain greater accuracy in making resistance measurements by using the G-E portable double bridge.

Designed for simple and quick measurements by a single operator, the bridge has only one dial to adjust, has a self-contained power supply and may be easily transported.

For maximum utility, this precision instrument has 8 ranges permitting measurements from 0.0001 to 22 ohms at an accuracy of 0.1 per cent of full scale, e.g. 0.000001 ohms at the lowest range. Price is $304.20*. Check coupon below for more information.

SECTION C605-21, GENERAL ELECTRIC
SCHENECTADY 5, N. Y.

Please send me the following bulletins:
Indicate:
√ for reference only
× for planning an immediate project
☐ Photoelectric Recorder GEA-5536
☐ Portable Double Bridge GEC-251
☐ Type PM-18 Oscillograph GEC-580
☐ 1952 Catalog GEC-1016

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Radio Interference and Field Intensity

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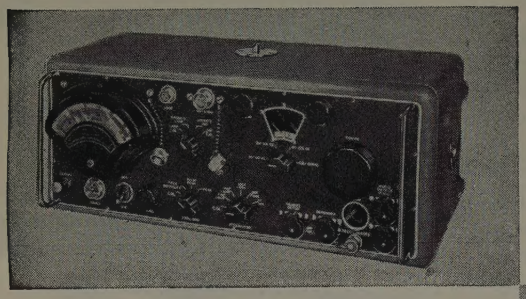
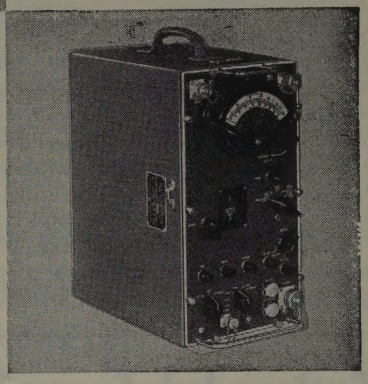
Complete Frequency Coverage -- 14kc to 1000mc!



NM - 10A VLF

14kc to 250kc
Commercial Equivalent of AN/URM-6.
Very low frequencies.

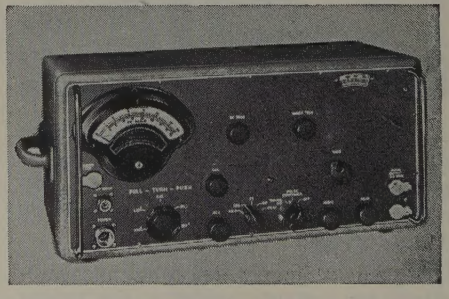


HF **NM - 20A**

150kc to 25mc
Commercial Equivalent of AN/PRM-1. Self-contained batteries. A.C. supply optional. Includes standard broadcast band, radio range, WWV, and communications frequencies.

NMA - 5A VHF

15mc to 400mc
Commercial Equivalent of TS-587/U.
Frequency range includes FM and TV Bands.



UHF **NM - 50A**

375mc to 1000mc
Commercial Equivalent of AN/URM-17.
Frequency range includes Citizens Band and UHF color TV Band.

These instruments comply with test equipment requirements of such radio interference specifications as JAN-I-225a, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a MIL-I-6722 and others.

STODDART AIRCRAFT RADIO CO.
6644 SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA
Hillside 9294

(*Continued from page 66A*)

chanical parts, hoses, and dielectrics, are described and illustrated.

Mechanical Development Apparatus. Servomechanisms, Inc., Westbury, N. Y., has issued a 16-page illustrated brochure, *MDA*-200, describing the complete line of precision components for rapid and economical assembly of control system instruments, and analogue computers for breadboard and semipermanent assembly. The brochure features an expanded line of new mechanical development apparatus components, including lead screw unit, clutch, bevel gears, limit stop, dials, cams, bellows and Oldham couplings, spring-loaded split gears, shaft adapters, block and switch assembly, and larger mounting board. The brochure is available on request on standard company letterhead from Servomechanisms, Inc., Westbury, N. Y.

Fastening Specialties. The Southco Handbook of Fastening Specialties, catalogue *B-2*, contains 22 pages of information on industrial fasteners for metal-to-metal and metal-to-wood applications. Blind rivets and a variety of door latching and fastening devices are illustrated in this book which also includes several pages of frequently used engineering data. Installation procedure, sample applications, and complete dimensional information are given for all fasteners. The catalogue is available from Southco Division, South Chester Corporation, Lester, Pa.

Applications of Thermostatic Bimetal. A 32-page booklet, "Successful Applications of Chace Thermostatic Bimetal," has been made available by the W. M. Chace Company, Detroit, Mich. The booklet, a summary of thermostatic bimetal, contains 18 uses of bimetal as the actuating element in temperature responsive devices and condensed engineering data for bimetal element design and selection. It is illustrated with various types of thermostatic devices employing Chace Thermostatic Bimetal. Copies may be obtained from the W. M. Chace Company, 1649 Beard Avenue, Detroit, Mich.

Radio-Frequency Equipment. The Daven Company, Newark, N. J., has prepared a pamphlet on R. F. Equipment, which is available now to the industry. This literature covers the many types of radio-frequency and television attenuators made by Daven. Requests for this pamphlet should be addressed to The Daven Company, Department RF, 191 Central Avenue, Newark 4, N. J.

Electric Connections. The 1952 catalogue of electric connections, including 20 pages on bus bar applications using the Cadweld Process, has been announced by Erico Products Inc., Cleveland, Ohio. The 76-page catalogue contains illustrations, drawings, charts, and order specifications.